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Master's Thesis

Drivers of residential water demand – analysis and outlook of water utility consumption data

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Abstract of master's thesis

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Abstract

Previous research has identified certain factors to have an influence on residential water consumption e.g. water metering, price and pricing policies, income level, age of residents, and building age. Their significance varies between countries and by location within an individual country. There is no previously published research on this topic in Finland or other Nordic countries.

Therefore, in this master´s thesis, an analysis of the common influencing factors on the residential water consumption at the metropolitan region Helsinki between 2004-2014 is provided, as well as predictions till 2040. The aim of this work is to evaluate the development of the residential consumption since 2004, and to identify influencing factors, which have a positive or negative influence on the consumption of the customers.

The influencing factors were analysed and statistically evaluated using a mix method approach with the provided consumption, population, and building information data. Block building type was identified to have the highest water consumption as well as the highest decrease in consumption during the observation period. Focusing on the drivers, the building age and the household size were identified to have the greatest influence on consumption. The expected decrease in consumption due to the use of individual meter was not identified. Water consumption schemes in the future were also analysed, and the predictions are presented for Helsinki on district level until 2025 and for the metropolitan region until 2040. The total consumption was found to increase as a result of rising population, while the consumption per person is decreasing due to the saving potential of renovations and technology. Espoo and Vantaa were identified to have the highest saving potential in per person consumption.

This thesis gives an overview of the past, current, and future water consumption in Helsinki, and provides a basis for future research.

Keywords residential water demand, socio-demographic factors, demand forecasting, Helsinki

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LIST OF ABBREVIATIONS AND ACRONYMS

Abbreviations

Shortcut	**Name**
ASYHT	Population per household (Asukkaat yhteensä)
AWWA	American Water Works Association
DMB	German tenants' association (Deutscher Mieterbund)
DSM	Demand-side management
Fitlm	Fit of the linear regression model
Gdb	Geodatabase (ArcGIS)
HEKA	Helsinki city apartments (Helsingin kaupungin asunnot Oy)
HSY	Helsinki region environmental service authority (Helsingin seudun ympäristöpalvelut –kuntayhtymä)
HWW	Water company of Hamburg Ltd. (Hamburger Wasserwerke GmbH)
IKA_KA	Average age per household (Ikäkeskiarvo)
JVWCD	Jordan Valley Water Conservation District
KAVU	Construction year (Käyttöönottovuosi)
KIITUN	Property ID (Kiinteistötunnus)
KOKOTUN	District code (Yhdistetty aluetunnus)
Mdl	Linear model

NEP	New Environment Paradigm
NEP- HEP	New Environment Paradigm- Human Exception Paradigm
PKOO	Y-coordinate (P-koordinaatti)
RAKTUN	Building Code (Rakennustunnus)
RWT	Rain water tank
SES	Socio-economic status
VVY	Finnish water utilities association (Vesilaitosyhdystys)
WEI	Water exploitation index
WDM	Water demand management

Formula Symbols

Latin Symbols

Symbol	**Unit**	**Name**
b	-	Regression coefficient
c	-	Constant in the linear regression equation
E	-	Residual error of the estimate for the calculation of the regression relationship for monthly water use
$N_{i,t}$	-	Number of units
P		Probability value
pop_t	-	Number of inhabitants in the observed year
pop_{t-1}	-	Number of inhabitants in the previous year
$pop_{t,new}$	-	Number of inhabitants in the new houses in the observed year
$pop_{t-1,new}$	-	New number of inhabitants in the previous year
Q	m^3/a, L/d	Water use
$q_{i,t}$	m^3/cap, L/cap	Consumption per unit of a customer category
$Q_{i,t}$	m^3/a, L/d	Demand for a given future time period
R^2	-	Statistical coefficient of determination
T	a, d	Future time period
t_{2003}	a	Year 2003
t_{2008}	a	Year 2008
V_i	M m^3/a	Interpolation coefficient of the total consumption
v_i	L/cap/d	Interpolation coefficient of the per person consumption
$V_{i,new}$	M m^3/a	Interpolation coefficient of the consumption of the new houses

$v_{i,new}$	L/cap/d	Interpolation coefficient of the per person consumption of the new houses
V_t	M m^3/a	Total consumption in the observed year
v_t	L/cap/d	Per person consumption in the observed year
v_{t-1}	L/cap/d	Per person consumption in the previous year
$V_{t,new}$	M m^3/a	Consumption of new houses in the observed year
$v_{t,new}$	L/cap/d	Per person consumption of new houses in the observed year
$v_{t-1,new}$	L/cap/d	Per person consumption of new houses in the previous year
x	-	Independent variable in the linear regression equation
x_{2003}	-	Factor age, tenants, building year in 2003
x_{2008}	-	Factor age, tenants, building year in 2008
X_i	-	Explanatory variable for the calculation of the regression relationship for monthly water use
x_{new}	-	New calculated factor age, tenants, building year
y	-	Estimated dependent score in the regression equation

Greek Symbols

Symbol	**Unit**	**Name**
β_0	-	Constant or intercept term for the calculation of the regression relationship for monthly water use
β_I	-	Estimated slope coefficient for the calculation of the regression relationship for monthly water use

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1 INTRODUCTION

Water is the basis of life, that is why it is so important for us. Water has always played a crucial role in the location, function and growth of communities (Arbués et al. 2003). Therefore water was declared as a human right by the United Nations in July 2010 (UN-Water 2014). Just 50 L/cap/d of water would be necessary (Willis, Stewart, Panuwatwanich, et al. 2011) to fulfil the basic needs of every human. The lifestyle of the western countries has developed so that much more water than needed is consumed, which goes along with two main problems. First, fresh water resources cover less than 1% of the total amount of water at the earth, they are limited (European Union 2011), and also not equally spread. Second, just 2% of the continental surface area is in use (Yalçıntaş et al. 2015), which additionally decreases the amount of accessible water sources. In addition, 50% of the world population are living currently in cities and the number rising up to 70% by 2050 (Yalçıntaş et al. 2015). Due to this reason, the stress on the water resources increase in the urban areas, which forces the water suppliers, policy makers, and city planners to react and balance between demand and available water resources to contribute in the future urban planning (House-Peters & Chang 2011). This process is supported by a water demand analysis. Climate change is causing an additional pressure on available water resources. Many parts of the world face more droughts because of temperature changes, while in other parts of the world the amount of precipitation increases, causing more floods (UNESCO 2012). Based on the ongoing economic and social progress, it is necessary to learn how to take care of the existing resources and learn ways to save water, e.g. through behaviour changes and technical improvements. However, this is mainly a challenge for the developed countries.

A closer look shows that even in Europe, water resources are unequally spread and climate change effects occur in various dimensions in the different countries. The differences in geographical and climatic conditions in Europe are causing problems in water supply for nearly half of the European citizens (European Union 2011). While the northern parts of Europe benefit from a wide range of fresh water resources as well as increasing precipitation (Irannezhad et al. 2014), the southern parts struggle with water scarcity, decreasing precipitation and droughts (Klaassens et al. 2012). In addition to natural effects also urbanisation and tourism are pressuring the available water resources and have worsened the overall situation significantly. Countries like Spain, Malta and Italy are already using nearly 20% of their long-term water resources (European Union 2011). In 2016, 73% of the European population lived in cities or urban regions, and this percentage is increasing up to 25% until 2025 (Hopp 2016). The main problem of urbanisation is the need of an adequate and punctual water supply at any time of the day for all residents, which poses a challenge for the local water utilities and also a pressure on the available water resources (Hopp 2016), especially in the case of water scarcity. 20-40% of the water resources are wasted (European Union 2011) through leakages, missing water saving technologies, unnecessary watering, and lack of knowledge among the people. On the other hand, especially the northern European countries have the privilege of water abundancy and water saving strategies are not a current need. This can be identified with the help of the water exploitation index (WEI), which represents the ration between the yearly extracted amount of fresh water and the available regenerative water resources as a percentage (Lutter et al. 2011). A percentage over 10% indicates an overuse of the resources, and value over 20% is a clear sign for water stress and an untenable consumption. The WEI for Finland in 2006 was 6% (Knoema 2017), for Sweden in 2010 1.5%, for Norway in 2007 0.8%, for Iceland 1.8%, and for Denmark in 2014 4.6% (Eurostat 2016).

To prevent misuse and overuse of the resources, the EU handed out policy guidelines and regulations. The main element is the European Water Framework Directive, which was implemented in 2000 (European Union 2011). One goal is to bring all responsible authorities within a watershed together to do all the necessary improvements for saving the existing groundwater and surface water resources, and to improve their ecological status to "good" until 2015 (European Union 2011). The European politics, related to water conservation, are based on the principle of the water hierarchy (European Union 2011). This means that additional infrastructures for water supply can be considered once all the other actions, e.g. water savings, improvement of the water efficiency, and pricing, show no beneficial effects on the reduction anymore (European Union 2011).

Integrated Water Resource Management (IWRM) is the key policy of the European Parliament to react on the current situation. IWRM tries to create a balance between demand and supply by using a range of approaches in consideration of the needed human activity, as well as the needs of the natural ecosystem (European Union 2011). Actions supporting the sustainable management of the water resources can be the usage of market-based instruments like block tariffing, imposing a fine for overuse or a discount based on the achieved savings (European Union 2011). Also, the development of new improved water infrastructures in watersheds, which must deal with extreme water scarcity and the implementation of water efficient technologies can support a sustainable use (European Union 2011). Other tools are educational programs to sensitise the population for the situation and learning ways to improve peoples' behaviour as well as the support of sustainable tourism (European Union 2011). One element to fulfil the required European regulations is to analyse the current and the future situation of water demand within a supply area. The results of the analysis and the discussed policy guidelines allow the different authorities to act accordingly.

This master's thesis is part of ongoing research in Water and Environmental Engineering research group at Aalto University. Previous research on the topic in other countries has shown that water metering, price and pricing policies, income level, age of residents, weather, building age, type of water using appliances, population density, and environmental awareness have an influence on the residential water consumption. Their significance varies between countries and by location within an individual country. No previous research can be found in Finland or other Nordic countries, so therefore this study covering the metropolitan region Helsinki is the first of its' kind. The objective of this thesis is to assess factors affecting residential water consumption in Finland with a comparison to Germany. With the help of this study the local utilities receive a support to figure out the development of the residential water demand, the saving potentials in their areas, and identifying meaningful policy actions on national level, e.g. imposing a fine for overuse – or whether any actions are necessary at all, in water abundant countries such as Finland and Germany. The metropolitan region Helsinki, including the cities of Helsinki, Espoo, Vantaa and Kauniainen as well as the Hanseatic city of Hamburg were chosen as research areas. The aim of this study is to find out how the water consumption has changed between 2004 and 2014, which factor has the highest influence on the residential consumption in the research areas, and how the consumption will develop until 2040. This is achieved by analysing different influencing aspects of water demand, e.g. population age, household size, building type and age, water meter type, and income.

Unfortunately, the data availability has led to the results that the former research plans cannot be as planned. Therefore, the analysis for Hamburg cannot be implemented, as well as the analysis of the benefits and pros and cons of the costs of water efficiency, water consumption drivers, and future trends.

2 THEORETICAL BACKGROUND

The actual pressures on water demand are the competing water uses as land use change, intensification of agriculture and industry, population growth, and urbanization (Russell & Fielding 2010). These factors will be aggravated by climate change (Russell & Fielding 2010). One tool to bring a balance between demand and conservation is water demand management (WDM). WDM is defined by the American Water Works Association (AWWA) as the task of selecting specific actions among a range of available options for meeting the target demands (Froukh 2001). Those management actions are based on an extensive analysis of the actual and future situation. Therefore, a responsible interaction of many different authorities, partly also transnational as well as the customers, is necessary. Some examples of WDM strategies are water metering, water restriction levels, water efficient devices, water consumption information devices, and education (Willis, Stewart, Giurco, et al. 2011).

This work will provide above-mentioned water demand analysis for the water utilities in Helsinki, Finland and Hamburg, Germany. The background study will present and explain the main drivers of water consumption behaviours, as well as give a small overview of the widely-used forecasting models followed by a short summary of four existing water demand prognosis reports.

2.1 Factors Influencing Water Consumption

The factors, which are influencing the water consumption behaviour of a person, are quite complex and hard to categorise. Some of them have a psychological background, as education, and can be changed e.g. through the influence of the environment. Other factors, as renovation, include modifications and can be implemented through either effort or investment. For a statistical analysis, it is therefore important to decrease the range of possible influencing factors, define certain factors, described with data, and enable the specification of possible water conservation actions in the end. Some main factors, which are significantly influencing the water consumption of a single person or a community, have been identified from the literature. The most important factors, which are also used for the water consumption analysis of this study, are explained in more detail in the following chapters.

2.1.1 Socio-Demographic Factors

Socio-demographic factors do not only provide information about the structure and development of our society. They are also a good instrument for dividing the population into general groups to analyse their current water consumption and to predict the consumption in the future.

Table 1: Effects of demographic trends on water consumption (Hummel & Lux 2007)

Demographic trends	Effects on water consumption
Decreasing population size	• Reduces amount of total water supply
Decreasing household size	• Increases water demand at household level because of inefficient water use
Increasing number of households and decreasing population density	• Increases total water supply in some cases because additional rinsing of pipelines is necessary in order to avoid microbial re-contamination of drinking water due to increased retention time • Potential loss of economies of scale in water supply
Demographic ageing and diversification of lifestyles	• Effects depend on the quantitative shifts in age composition but have not been sufficiently investigated yet

2.1.1.1 Household Size

The household size is a significant indicator for water consumption (Billings & Jones 2008). Previous studies conclude that with the increase of the household size the water consumption per person decreases (Schleich & Hillenbrand 2009; Willis et al. 2011; Hummel & Lux 2007; Arbués et al. 2003; Russell & Fielding 2010).

The main reason is that, even though more consumers are present, the water use in bigger households is more efficient compared to single households (Hummel & Lux 2007), as they most likely have e.g. full laundry machines and dishwashers. Nevertheless, a closer look at the end use consumption shows that the total amount of water used per person for laundry machines and toilets is generally higher in bigger households (Willis, Stewart, Panuwatwanich, et al. 2011). Willis et al. (2011) explain this with the probably larger number of children, which in many cases live within big families. In the end, as Schleich & Hillenbrand (2009) reported, the per capita water consumption decreases when the household size increases, because the needed amount of water for various water uses increases proportionally less than the number of people living within a household increases.

2.1.1.2 Population Age

One of the most widely used factors to group the population is age. The age of a person have influence on personal capabilities, among other things, and this in turn predicts persons' water consumption (Russell & Fielding 2010). According to Schleich & Hillenbrand (2009), an increase in age is related to an increased water consumption. It was stated that an increase in the average age by one year leads to an increase in daily water consumption per person by about 1.8 L (Schleich & Hillenbrand 2009). The reasons behind this increase in water consumption are the life circumstances of older and retired people, as they spend in overall more time at home with e.g. gardening, cooking, and cleaning. Moreover, their state of health is related to a more frequent use of the bathroom, which calls for a higher need of water. Study by Williamson et al. (2002) came to the same conclusion.

Contradictory, a study from 2002 made by the Organisation of Economic Co-operation and Development in the Netherlands concluded that the age group of 18-24 years' olds consumes, with a maximum demand of 149.6 L/cap/d, much more water than the age group of 65 years' and older people, 118.6 L/cap/d (Hummel & Lux 2007). Also Corbella & Pujol (2009) came to the same conclusion that older people tend to use less water. According to their study, families with children or teenagers in Barcelona, Spain are the highest consumer group, which is generally due to outdoor water use.

The examples from previous studies show, that there is no linear relationship between age and water conservation. Therefore, it is impossible to generalize the behaviour of a certain age group. The factors behind behaviour are complex as the stage in live, circumstances as well as the experiences of a generation differ from each other and within an age group. However, even if this factor cannot be generalised, it might be used to get an overview of the water consumption behaviour within the age groups in the research area and to implement the results in the end into the water consumption forecast.

2.1.2 Building Type, Age, and Ownership

Some of the most important factors, influencing water consumption are building type and age. They are one of the factors modifiable with effort and investment. If the water consumption is investigated based on the building type, it can be distinguished between apartment blocks and detached houses. If the focus of the analysis is set on a comparison of those two residential building types, then the residents of a detached house are expected to be the higher water consumers (Randolph & Troy 2008). According to Willis et al. (2013) as well as Randolph & Troy (2008), this is based on the fact that a detached house has more space, sometimes several bathrooms, and a larger garden area, which can also include other water consuming facilities e.g. pool, outdoor shower, or sauna. This accounts for the Gold Coast and in Sydney, Australia. De Oliver (1999), Gilg & Barr (2006) and Clark & Finley (2007) concluded that residents of detached houses have greater intensions to conserve water, which is contradictory to the previous results. These studies were performed in San Antonio, Texas, Devon, UK, and Blagoevgrad, Bulgaria. Therefore, it seems that the results and reasons can vary depending on the study area. A third opinion was given by Lam (2006), who found out that in the cities Taipei and Kaohsiung in Taiwan, Republic of China residents of detached houses show less intensions to conserve water. The reason is that the residents of detached houses do not share their water tanks with their neighbours compared to apartment buildings. Hence, he concluded that culture-specific characteristics need to be considered too. These proofs that the results and reasons, explaining the different usage behaviour of residents either in apartment buildings or detached houses, vary depending on the study area.

According to Randolph & Troy (2008), the aspect of living in detached house, semi-detached house or a flat in a block or apartment building, has little impact on the average individual water use. This is in contrast with the studies presented in the previous paragraph. Randolph & Troy (2008) state that the aspect of owning or renting a building or apartment is more significant and can influence the attitude regarding the water use of the residents. Furthermore, Billings & Day (1989) found that an increase of 10% in the number of home owners leads to a decrease of 1.8% in the total water use in Southern Arizona. Homeowners seem to be more aware of their water consumption and more open to water conservation actions. This can be reasoned by the fact that in presented case in Southern Arizona as well as in Finland the use of individual water meters is still not that common, which disables the tenant to be informed about their actual consumption (Billings & Day 1989). Furthermore, property owners have the possibilities to install water conserving fixtures (Russell & Fielding 2010; Billings & Day 1989) and they are more willing to invest in those changes as an improvement of their own home (Randolph & Troy 2008).

Building age affects more the water consumption than building type, as in the last years the water appliances in buildings have improved a lot and became more efficient regarding to water conservation. In addition to reduced water consumption, the more recently installed pipe systems and water appliances are less prone to leak, which decreases the unintentional water consumption. Faulty toilet valves account for the main part of household leakages (Agthe & Billings 2002). In the Jordan Valley Water Conservation District (JVWCD) case, 44% of the water savings were achieved just through the replacement of leaking toilets, indicating that not renovated houses are supposed to be higher water consumers than new or renovated buildings (Agthe & Billings 2002). The biggest change can be achieved by replacing old appliances with new water saving devices. In the study about the effectiveness of demand-side management (DSM) tools, Inman & Jeffrey (2006) found out that retrofit programs can achieve a reduction of 9-12% in water consumption, while the replacement of household appliances with more highly efficient appliances reduces the consumption about 35-50%. Retrofitting is the installation or fitting of a device for use in an existing structure, e.g. swapping to a low-flow shower head (Water Resources Engineering Inc 2002). In case of a replacement, the whole shower is changed into a water-saving model. Therefore, retrofitting is an intermediate step between repairing and replacing of an item. According to another study by Aarnisalo (2016) an decrease in consumption of 10-17% can be achieved due to pipe repairs' and renovation of the water fittings. Those reduction effects can only be seen for a certain amount of time. After a phase of development and implementation of sustainable water saving measures in households, the potential of the technique is achieved and exhausted (Kluge et al. 2014). The development and implementation phase goes along with a significant decrease of the total water consumption. Consumer behaviour is expected to be fairly stable in the foreseeable future, so that only moderate declines in the per capita water demand occur (Kluge et al. 2014).

2.1.3 Water Metering

This factor does not just influence the demand behaviour of the residents, but it also defines the empirical basis for the analysis of the water consumption. The usage of water meters allows the residents as well as the utilities to assess the consumption behaviour and to test the effectiveness of the applied water demand management actions (Corbella & Pujol 2009). Since 1968 economists have defined the metering of the water consumption as an effective tool to reach greater efficiencies in the use of water (Corbella & Pujol 2009) due to the knowledge about individual consumption and consumption-based billing, which have an impact on water usage behaviour of the customers (Billings & Jones 2008). On the other hand, this provides a possibility for the utilities to track the system performance and check on possible leakage points by comparing the delivered and consumed volume of water (Billings &

Jones 2008). Thus, it is quite common in the western world to use water meter for tracking the consumption and bill the consumers based on it. By using the smart water metering technologies, it is also possible to collect precise real-time empirical data about where and how often water is used in the home (Willis, Stewart, Giurco, et al. 2011). This gives planners and conservationists the chance to determine the savings, which are achievable through the usage of water demand management (WDM) strategies. Furthermore, water utilities have a better possibility to measure and manage the effectiveness of the water supply as well as distribution systems within their supply area (Willis, Stewart, Giurco, et al. 2011).

Especially for apartment blocks, there are two different ways to track the consumption of the residents. One option is to measure the consumption of the whole house (building level) and bill the tenant either according to the number of residents within an apartment or the living space (German Tenants Association n.d.). Another way is to install a water meter (household level) in each apartment and bill the tenant by their individual consumption. The differences between these two billing options and influences they have on the water consumption of the tenants are explained in the following paragraphs.

2.1.3.1 Water Meter Type

According to the literature water metering on building level provides no economic incentive for occupants of the apartment to change their water usage behaviour (Agthe & Billings 2002). First, they have no information about their individual consumption, which makes it impossible to get an idea how much they actually use water and if it is necessary to conserve water. Furthermore, they have to pay a fixed price, as it was explained in section 2.1.3, which is already included in the rent or maintenance charge in form of incidental costs (Tenancy law dictionary 2013). This can lead the occupant to lose track of the value of clean water and in many cases even to see water as a free good (Agthe & Billings 2002). On the other hand, data achieved through water metering on building level makes the analysis more imprecise, as the calculation of the specific water consumption can just be done by dividing the overall consumption by the number of tenants.

Compared to the metering on building level, tracking the water consumption with help of individual meters at the apartment level has the advantage of improving the knowledge of each customer about their actual water consumption (Inman & Jeffrey 2006). This specific knowledge is significantly related to a lower demand and was shown to be more important than customers' beliefs about water conservation in reducing water consumption (Inman & Jeffrey 2006). The study performed by Toivanen (2010) showed that the water consumption was reduced by 8.8% through the introduction of individual meter, during the research period from the 1.04.2009 till the 31.03.2010. The study was implemented for the "Housing Corporation Turun" at Linnankatu 29 in Turku, Finland. The requirements regarding to the used water meter type are regulated in Finland and Germany by law. In Finland, the mandatory installation of apartment meters in new buildings came into force in 2011 and during corresponding renovation works in 2013 (Finnish Ministry of the Environment 2010). Even though installing individual meters is compulsory, billing based on them is not. Since 2006 in Hamburg, it is required to install individual meters for all apartments in existing as well as new buildings, and to bill the tenants based on those meters (Zenner 2003).

2.1.4 Water Pricing

The pricing of water is a financial tool or economic instrument (Inman & Jeffrey 2006; Corbella & Pujol 2009), which was initially predicted to influence consumption (Willis, Stewart, Panuwatwanich, et al. 2011). One example about the influence is presented in the work of Corbella & Pujol (2009) regarding to a decreasing water consumption in East Germany after the unification based on the financial incentives (price increases) and technological changes.

Often the water price is a mixture of fixed and variable components. The fixed component is the basic fee, which entitles the customer for the water consumption. In addition to that, as the variable component, the consumer subsequently pays an additional smaller amount per unit (quantity price) (Arbués et al. 2003). Based on this pricing concept, the assumption that higher water prices lead to lower consumption is logical, if water is treated as a pure economic good (Corbella & Pujol 2009). However, water is not a normal economic good, as water is irreplaceable in our daily lives (Corbella & Pujol 2009). Moreover, it must be acknowledged that the demand fluctuates based on the seasons of the year (due to weather effects), the day of the week and the hour of the day. Therefore it would be necessary to use seasonal or peak-price tariffs, if water conservation promotion as well as an efficient water use are requested among the utility (Arbués et al. 2003).

More generally the price influences water demand if the elasticities are different from zero (Arbués et al. 2003). The price elasticity is a tool used in microeconomics to measure the response of the quantities demanded or supplied to a change in price (OpenStaxCollege n.d.). If the quantity demanded or supplied responds to price changes in a greater manner than the price is elastic (OpenStaxCollege n.d.). If a change in price causes a smaller change in the quantity demanded or supplied than the price is called inelastic (OpenStaxCollege n.d.). As the price elasticity of demand is defined as the percentage change in the quantity demanded of a good divided by the percentage change in the price (OpenStaxCollege n.d.), a measured price elasticity different from zero will influence the water demand (Agthe & Billings 2002). Based on this, the general domestic consumption price-elasticity oscillates between 0 and -1, and may also vary over time (Corbella & Pujol 2009). More basic and essential the usage of water is, the value of the price elasticity gets closer to zero (Corbella & Pujol 2009). Economists working on domestic water, the water which is used for all indoor and outdoor household purposes (U.S. Geological Survey 2000), and most of the previous researches have concluded that water demand is relatively price inelastic (i.e. demand responds disproportionately to the changes in water pricing) (Inman & Jeffrey 2006). This means that the decrease in demand is lower than the increase in price (Corbella & Pujol 2009). As a result, price mechanisms would not make a great difference if the consumed quantity of water is equivalent to the quantity to fulfil the basic and essential needs (Corbella & Pujol 2009). Previous studies have determined that outdoor water use is more price elastic with a price-elasticity of -1 (Corbella & Pujol 2009). Inman & Jeffrey (2006) calculated an average price elasticity for the residential water demand to be -0.28 in Europe, -0.005 in the Eastern United States, -0.17 in the Western United States, and between -0.60 and -0.80 in Australia.

Another fact is that price elasticity is likely to be greater in low income households, where water costs form a greater proportion of the household income (see section 2.1.5) (Russell & Fielding 2010). Therefore the usage of these pricing mechanisms disproportionately affects the low income households and raises issues about equity and fairness (Russell & Fielding 2010). The option of marginal pricing may serve the purpose of efficiently meeting the costs of supplying the water, but not the aim of providing incentives for efficient usage of water (Inman & Jeffrey 2006). Marginal-cost pricing is the practice of setting the price of a product so that the price is equal to the extra costs of producing an extra unit of output (Editors of Encyclopedia Britannica 2006), which means that the price is set so that it is higher than the marginal costs but lower than the full costs for this product (Business Dictionary n.d.). It is critical to choose the correct pricing schemes in order to balance between equity and efficiency, as well as to achieve the greatest conservation potential in outdoor uses, while not transmitting the conservation burden for essential uses (Corbella & Pujol 2009). Moreover, pricing still leaves an option of voluntary behaviour, because everyone can decide on their own if they can afford that luxury or not (Inman & Jeffrey 2006). So pricing mechanisms are more a way of introducing water conservation rather than pointing out that conservation is required (Inman & Jeffrey 2006), at least for the part of the population which can afford a decision like this (see section 2.1.5).

In Germany the water price is based on the cost covering principle (German Government 2006). The water price should cover the expenditures on water services as well as the environmental and resource costs (German Government 2006). Therefore, the water price is determined by a consumption-independent component (basic price, in average 12%) and a consumption-dependent element (quantity price, in average 88%). This price regime was established under the condition and the assumption of continuous growth of economy, population, and water demand. During the last years, most of the water utilities in Germany, especially in the rural areas, were dealing with a declining population and changing user behaviours. This reduced water demand has also economic consequences, leading to the increase in the cost of water per person, even in case of a constant individual consumption. As long as the total costs are covered, this calculation works out. (Hummel & Lux 2007)

The prices for water in 2017 are 1.40 €/m^3 in Helsinki (HSY 2016) and 1.85 €/m^3 (Water Company of Hamburg 2017). Fixed basic rate is 0.0196 €/floor-m^2/month in Helsinki (HSY 2016) and 2.55 €/month in Hamburg, in case of just one water meter and an average flow of 1.5 m^3/h (Water Company of Hamburg 2017).[1] The water price in Helsinki region is lower than the median price in Finland (Nurminen 2016), even if the price has increased more than 15% during the last 13 years (Ahopelto et al. 2015).

2.1.5 Income Level

The income level plays also an important role when it comes to water consumption. It was stated that customers react to the level of the water price (see section 2.1.4). This explains the main reason why families with a higher income have a higher water consumption compared to

[1] The listed water prices are already the gross price.

families with a lower income (Willis et al. 2013; Agthe & Billings 2002). Billings & Jones (2011) found also that the consumption increases when family income rises and decreases again when the primary breadwinner loses ones' job. In another study about the demand management factors in residential water use, Billings & Day (1989) reported that in Southern Arizona a 10% increase in the average household income tends to produce a 3.3% increase in water use. They also found that the average expenditures on water ranged between 1-2% of the household income, whereby the higher ratios were detected in the districts with the lowest income. This indicates that the consumption and the income are positively correlated.

Income level has also an effect on the responsiveness to price mechanisms (Corbella & Pujol 2009). Prices can be used as a regulatory tool to achieve a certain goal (Inman & Jeffrey 2006). But overall, water pricing allows a voluntary behaviour based on the personal financial capabilities (Inman & Jeffrey 2006). This means that the current price signal is not strong enough and therefore the water price is rather introducing a conservation behaviour than requiring it (Corbella & Pujol 2009; Randolph & Troy 2008). On the other hand, customers with a lower income have already reduced their water consumption to a level where they can fulfil their basic needs in order to have a low water bill, so they may also be resistant to the pricing mechanisms (Corbella & Pujol 2009). Another reason is that the income level and the lifestyle are connected to each other (Corbella & Pujol 2009). An increase in income level can lead to changes in lifestyle. This on the other hand can imply a change of the housing situation (e.g. bigger apartment or house) a higher range of water-consuming appliances (e.g. tube or multifunctional shower system) as well as a higher probability of the presence of high-water demanding outdoor uses (e.g. lawn gardens or swimming pools) (Corbella & Pujol 2009). Furthermore, a combination of the factors presented in previous sections as well as the income level determines the individual water consumption of a person.

2.1.6 Environmental Awareness

The environmental awareness of a person is a psychological factor, which is hard to measure, but plays a significant role in water usage behaviour related to water demand (Willis, Stewart, Panuwatwanich, et al. 2011). Previous studies show that specific beliefs about water and water conservation are the most immediate drivers in contrast to general environmental beliefs (Inman & Jeffrey 2006; Russell & Fielding 2010; Willis, Stewart, Panuwatwanich, et al. 2011). If people see water as an important and limited good, they are more committed to water conservation behaviours (Russell & Fielding 2010). The way people think about the environment and their resources is influenced by their social environment, education, country of resident, and partly by political campaigns (Inman & Jeffrey 2006).

The social environment is one factor, which is influencing a persons' awareness on water conservation (Russell & Fielding 2010). Already in the early years the water using behaviour is characterised due to the family communication and education. It was stated that in many cases the conservation behaviour were often started by one family member and subsequently adopted by the others (Russell & Fielding 2010). Inman & Jeffrey (2006) refer in their work to a study of the AWWA from 1992 and their result that public education programs in the USA, which urge people to conserve water, significantly reduce the water demand in the western part of the USA where water scarcity is more of a problem. This shows that also environmental issues in the living environment play a crucially role, when it comes to the effectiveness of water conservation programs. The effect on the water conservation through public awareness programs is expected to reduce the demand by 2–5%, but it exists just for a temporary time period (Inman & Jeffrey 2006).

Table 2: Revised NEP Statements (Anderson 2012)

1. We are approaching the limit of the number of people the Earth can support.
2. Humans have the right to modify the natural environment to suit their needs.
3. When humans interfere with nature it often produces disastrous consequences.
4. Human ingenuity will insure that we do not make the Earth unlivable.
5. Humans are seriously abusing the environment.
6. The Earth has plenty of natural resources if we just learn how to develop them.
7. Plants and animals have as much right as humans to exist.
8. The balance of nature is strong enough to cope with the impacts of modern industrial nations.
9. Despite our special abilities, humans are still subject to the laws of nature.
10. The so-called "ecological crisis" facing humankind has been greatly exaggerated.
11. The Earth is like a spaceship with very limited room and resources.
12. Humans were meant to rule over the rest of nature.
13. The balance of nature is very delicate and easily upset.
14. Humans will eventually learn enough about how nature works to be able to control it.
15. If things continue on their present course, we will soon experience a major ecological catastrophe.

The concept of the New Environment Paradigm-Human Exception Paradigm (NEP- HEP) was developed to measure people's general environmental beliefs and their ecological worldview (Willis, Stewart, Panuwatwanich, et al. 2011). More in detail, in NEP the believes about the limits of nature and resources, human impact on the balance of nature, humans' right to dominate over nature, and the potential for ecological catastrophe are measured with the NEP survey scale (Russell & Fielding 2010). Fifteen statements of the revised NEP survey are listed in table 2 and they are rated by using a Likert-scale. The Likert-scale is a rating system, where the respondent needs to indicate his strength of agreement (strongly agree, agree, unsure, disagree, strongly disagree) for each statement (Anderson 2012). To analyse the effect of attitudes on the actual water end use consumption, the end use water consumption data and attitudinal questionnaire survey data are compared (Willis, Stewart, Panuwatwanich, et al. 2011). Willis et al. (2011) showed that pro-environmental and water conservational attitudes result in savings in the total consumption and across the most end uses, which are not satisfying basic needs. This is because the end use consumption varies entirely based on the consumption decision of the water users. In the end, the challenge for policy makers is to identify the most important and salient beliefs associated with water conservation as well as provide effective guidelines and programs to promote water conservation (Russell & Fielding 2010). It is necessary that future research moves toward to measure both, water conservation intentions and the actual water use (Russell & Fielding 2010).

2.1.7 Climate

The climate conditions are another influencing factor of the residential water consumption. The most influential climate variables are rainfall and temperature, which both mainly affect the outdoor water use (Corbella & Pujol 2009; Billings & Jones 2011; Miaou 1990). The precipitation patterns, especially in an urban environment, determine the water needs of the plants and the lawn, which need to be covered by network water (Corbella & Pujol 2009). The temperature, on the other hand, influences the evapotranspiration and so the need of humans and vegetation to be hydrated (Corbella & Pujol 2009). Especially high temperatures cause a higher degree of evaporation both from humans and vegetation, as well as increase the need for garden watering, swimming pool use, and personal hygiene (Corbella & Pujol 2009). In regard to outdoor water use this can also include a frequent refill of the swimming pool, which will increase the water consumption (Corbella & Pujol 2009). All this leads to a variation in the water consumption between the seasons.

The influencing factors mentioned above also depend on the local climate. While warmer climate zones face a summer peak in demand to compensate all the aforementioned aspects, some colder climate zones have to manage with a peak demand during winter time (Billings & Jones 2008). The reason is that a continuous flow in the system must be obtained to prevent damages in the pipe system, caused by frost at cold days (Billings & Jones 2008). The urban water demand can be significantly influenced by climate change, as the previous studies generally predict an increase of the number of extremely hot days (Billings & Jones 2008). In Hamburg, the summers will be drier and hotter. Therefore, the precipitation will be within a range of ±6%, and the temperature will be range between 0.9-1.6 °C, during the period of 2031-2060 (Kluge et al. 2014). This can lead to an increase of about 1% in the average daily water consumption in the summer (Kluge et al. 2014). In Finland, however, there will be an increase in seasonal precipitation in winter (4–57%) and spring (1–37%) during the period 2040–2069, and in autumn (3–35%) between 2070 and 2099 (Irannezhad et al. 2014). Irannezhad et al. (2014) projects also that the annual precipitation is increasing 0–30% by 2050.

2.2 Forecasting Methods

Water consumption forecasting methods are the techniques and practices used to analyse the past water consumption and to apply the knowledge in the future (Froukh 2001). The forecasted values of one or more variables (e.g. population, income, water price) will be translated into estimates of future water requirements (Froukh 2001). That defines the knowledge of the historical water use as the basis input variable of the model (Billings & Jones 2008).

Forecasts can be classified into different time horizons according to the user purpose, the necessary level of reliability and the forecast model (Billings & Jones 2008). The relevant classifications, their forecast horizons, and examples for their application are listed in table 3.

Table 3: Water demand forecast types and application examples (Billings & Jones 2008)

Forecast Type	Forecast Horizons	Application
Long-Term	Decades 10-15 years	sizing system capacity
Medium-Term	Years-Decades 7-10 years	staging treatment and distribution system improvements

In general, long-term forecasting methods include time-extrapolations, disaggregated end-uses, single-coefficient methods and multiple-coefficient methods (Donkor et al. 2012). The greatest difference between the existing methods is the way how the per capita water consumption forecast is obtained and the degree of classification by customer type (Billings & Jones 2008).

A wide range of different methods, from simple to complex as well as from qualitative to quantitative, can be found in current literature (Froukh 2001). Some of the common ones were used since the beginning of the existence of water demand forecasts, while others were developed in the last years based on the technical improvements of computers and computer programs. The basic approach of the forecasting methods can either be analytical, mathematical or heuristic (Froukh 2001). The appropriate forecasting method is chosen depending on the needed technical perfection of the analysis, the dedicated resources and the available data (Billings & Jones 2008).

In case of the data, the periodicity of the used data variables play a key role while choosing the appropriate method (Donkor et al. 2012). According to Donkor et al. (2012), most interesting data used in urban water demand forecasting are: monthly total system demand, annual per capita demand, annual demand by customer class and revenue. In the following sections three predominant quantitative forecasting methods and their mathematical models are explained in more detail.

2.2.1 Unit Water Demand Analysis

Unit water demand analysis is one of the simplest models and widely used by most of the utilities (Donkor et al. 2012). Even large water utilities analyse their future water demand based on a calculated unit water use coefficient of a customer category, i.e. residential, industrial, commercial and public (Billings & Jones 2008). To forecast the water demand ($Q_{i,t}$) for a given future time period (t), the current consumption per unit of a customer category ($q_{i,t}$) needs to be estimated and multiplied with the future number of units in that category ($N_{i,t}$) (Donkor et al. 2012). Total water demand of the network can be forecasted by adding the water demand of the customer categories together (Donkor et al. 2012). The mathematical expression is presented in formula 1, where for C customer categories, indexed by i, the demand forecast at t is given by:

$$\sum_{i=1}^{C} Q_{i,t} = \sum_{i=1}^{C} q_{i,t} * N_{i,t} \qquad \textit{Formula 1}$$

The way of modelling makes the reliability of this forecast model questionable, as there are simple general rules or the judgement of the user used instead of empirical analysis to estimate $q_{i,t}$ and $N_{i,t}$ for each customer category (Donkor et al. 2012).

2.2.2 Time Series-Models

Time series models make it possible to use historical water use trends and to project the future water use. A variety of techniques like simple time trends, exponential smoothing, and Box-

Jenkins models are used to calculate an autoregressive integrated moving-average for the data (Billings & Jones 2008). The projection is based on the assumption that it is possible to predict the future changes using historical trends (Billings & Jones 2008). This is also the main point of criticism of this model. Because of this assumption, influencing factors like demographic, economic, and technological changes as well as the implementation of WDM strategies during the observed period, are going to be neglected (Donkor et al. 2012). As the relevance of these factors was indicated before, it is evident that this has an influence on the accuracy of the results, if past and future circumstances are not clear (Billings & Jones 2008). The accuracy can be improved by dividing the water consumption to each classified customer group, and taking into account the geographical characteristics if possible (Billings & Jones 2008). Through these extrapolation methods are limited for long-range forecasts (Billings & Jones 2008). The usage of time series models is more appropriate for the modelling of short–term and medium-term forecasts, because the variation of the influencing factors is expected to be negligible at these time periods (Donkor et al. 2012).

2.2.3 Regression Models

Using regression models to perform water consumption forecasts is more complex, because they are based on common-sense theories about cause and effect, and include therefore the necessary influencing factors e.g. water prices, personal income, and population (Billings & Jones 2008). Compared to the aforesaid models, a regression model describes the important aspects of how the world works, as the user has the possibility to predetermine the relationships between variables and to find or estimate future values of those independent variables (Billings & Jones 2008). Regression models can be created using cross-sectional data, time series data, or panel data (Donkor et al. 2012). Dependent and explanatory variables are determined, as well as the functional form of the regression is defined in the beginning of the analysis (Billings & Day 1989).

Formula 2 presents the regression relationship as a mathematical expression. The variable on the left side of formula is the dependent variable (Q), which is attempted to be explained by the explanatory variables (β_i and X_i), the constant term (β_0), and the error term (E) on the right side of the formula. In other words, the right side of the formula is specifying the model (Billings & Day 1989). In this particular case (Formula 2), Q is the water consumption, β_0 is the constant term of the regression, β_i and X_i are the coefficient and observed value of the i-th independent variable, and E is the residual or error term of the estimate (Billings & Jones

2008; Donkor et al. 2012). It is required that the error terms are independent of each other (Donkor et al. 2012).

$$Q = \beta_0 + \sum_{i=1}^{n} \beta_i * X_i + E \qquad \textit{Formula 2}$$

After determining the necessary variables and running the model, estimates of the values of the variables β_i and X_i, as well as other information valuable for diagnostic testing (i.e. goodness of fit, statistical significance, and adequacy) are generated (Billings & Jones 2008). The goodness of fit of β_i is most commonly measured with the coefficient of determination (R^2) and is used for evaluating the regression (Billings & Jones 2008). Each calculated coefficient show the change in the dependent variable for a one-unit change in that specific explanatory variable, while keeping all other explanatory variables constant (Billings & Jones 2008). Every regression coefficient can be seen as the partial derivative of the dependent variable with regard to that specific explanatory variable (Billings & Jones 2008). The size of the coefficient depends on the way the explanatory variable is defined (Billings & Jones 2008).

2.3 Existing Case Studies

The range of literature on this topic is quite wide but existing case studies mostly refer to countries like Australia (Gato et al. 2007; Willis et al. 2011; Willis et al. 2013) and America (Billings & Day 1989; Chang et al. 2010). A few studies were performed for Europe, for instance for Istanbul, Turkey (Yalçıntaş et al. 2015) and Barcelona, Spain (Corbella & Pujol 2009). Also general studies for Germany do exist (Hummel & Lux 2007; Schleich & Hillenbrand 2009). In the following sections the most important facts about two existing studies within the research areas and of two studies beyond the research areas are summarised.

2.3.1 Gold Coast – Queensland - Australia (Willis, Stewart, Giurco, et al. 2011)

In previous study about the Gold Coast residential end use, Willis et al. (2013) analysed the relationship between socio-demographic variables and evaluated the effectiveness of WDM strategies, e.g. application of water efficient devices and education programs. Therefore Willis et al. (2013) identified the water end use consumption levels for 151 households in the city Gold Coast as well as the dedicated suburbs Pimpama-Coomera, and Mudgeeraba in Queensland, Australia. The city has 510,000 inhabitants who used approximately 157.2 L/cap/d of water in 2008. The residential water consumption accounts for approximately 66% of the total supply in the years 2007 and 2008. The extreme drought, which occurred in 2008, might have had an influence on the water consumption habits or on a range of other contributing factors.

Smart metering was implemented to collect the necessary data for end use water consumption of each of the household used devices, to understand the saving potential of efficient devices, and to enable a comparative analysis between shifting household socio-demographic clusters. The main aims of this study are to:

1. Establish a household level and per capita water consumption end use break down;
2. Investigate the relationship between household stock survey efficiency rating clusters and water end use consumption levels;
3. Determine the demographic information of water users and the influence of socio-demographic factors on water consumption.

To analyse all this, a mix methods approach was used by utilizing qualitative and quantitative data. The data collection procedure includes individual household audits to document the existing types of water using fixtures and appliances in the households. The aim is to gain a snapshot of the water consuming devices within the researched regions, and to rate the efficiency of these devices in relationship with the water end use consumption levels in the end. Another part of the procedure is the end use water consumption study, for which two attached main processes were adopted. The first one is the physical measurement through smart meters with subsequent remote transfer of high-resolution data and the second on is a documentation of water use behaviours of the individual household by keeping self-reported water use diaries. The third part is a questionnaire survey, which was developed to obtain socio-demographic information of each household to realise the clustering and analysis of the varying demographic indicators. Willis et al. (2013) used clustering to classify the consumption in relation to the socio-demographic information and documented water consuming devices.

Willis et al. (2013) analysed the following socio-demographic factors: location of the household, lot size, rain water tank (RWT) ownership, household income, and makeup and detected the following results. To get a better understanding about, which water end use categories are more influenced by socio-economic regions, categories need to be examined individually. The socio-economic regions are defined based on the socio-economic status (SES). SES defines the social standing or class of an individual or group, and it is measured as a combination of education, income, and occupation (American Psychological Association n.d.). The results of Willis et al. (2013) show that the lower socio-economic groups tend to use slightly more water than those in higher socio-economic groups, in most of the end use categories. However, higher socio-economic regions are having a higher irrigation end use consumption, which can be connected to the lot size or the social pressure on the represents of garden. Moreover, the increase in the household income is connected to an increase in the water consumption. Willis et al. (2013) calculated, that lower income households consume approximately 8% less water in the Gold Coast City. The lower irrigation component leads to lower overall usage. An increase of the family size results in a general decrease of the per person consumption. Even through the fact that a closer look on the end use consumption shows, that larger families spend more water for the clothes washer and toilet. The actual achieved savings can be associated with the installation of efficient water use devices after the drought period in 2008, as the number of efficient water use devices has increased compared the previous research investigations. The last conclusion of Willis et al. (2013) is that the savings, which were achieved through WDM programs, have a flow-on benefit to the entire water and wastewater system, e.g. reduction of the peak hour demand of potable water. This can postpone the need of upgrading the water supply pumps and pipe infrastructure.

2.3.2 Tucson - Southern Arizona - USA (Billings & Day 1989)

Billings & Day (1989) analysed the response of water use to variations in price, household income, the variety of socio-economic (income, education, and occupation), as well as climate variables (temperature, precipitation, and evapotranspiration) in the metropolitan region of Tucson, Arizona. They used two models, an average-price model, and a marginal-price model, with the data from the three local utilities, the Tucson Water Department, the Flowing Wells Irrigation District, and the Community Water of Green Valley, for the period of 1974-1980. The average-price model approach assumes that the typical consumer responds to the average price of water. This can be calculated by dividing the monthly water bill by the consumed water quantity. The marginal-price model approach assumes that the consumers are well-informed about the rate structure and that they know the cost of unit of water. The area is supplied with groundwater and is facing a rapid growth of the population. Already 500,000 people inhabited the area in 1989. Besides that, it needs to be mentioned that Tucson have been successful in the implementation of their water conservation plans to not overexploit the groundwater resources. This success is mainly based on a public conservation program, which started in 1977. During the study period of 1974-1980 the authorities tried to reduce the consumption and raise the needed revenues at the same time. Therefore, the water rates have been restructured with the goal to increase the per-unit charges. This led to a substantial reduction of the water consumption at all three utilities. The strong relationship between price and consumption is illustrated in figure 1, which proves the power of the water price as a conservation tool. To prevent this effect Billings & Day (1989) recommend that the utilities accurately need to estimate the price-quantity relationship, so that rate adjustments bring desirable changes in revenues.

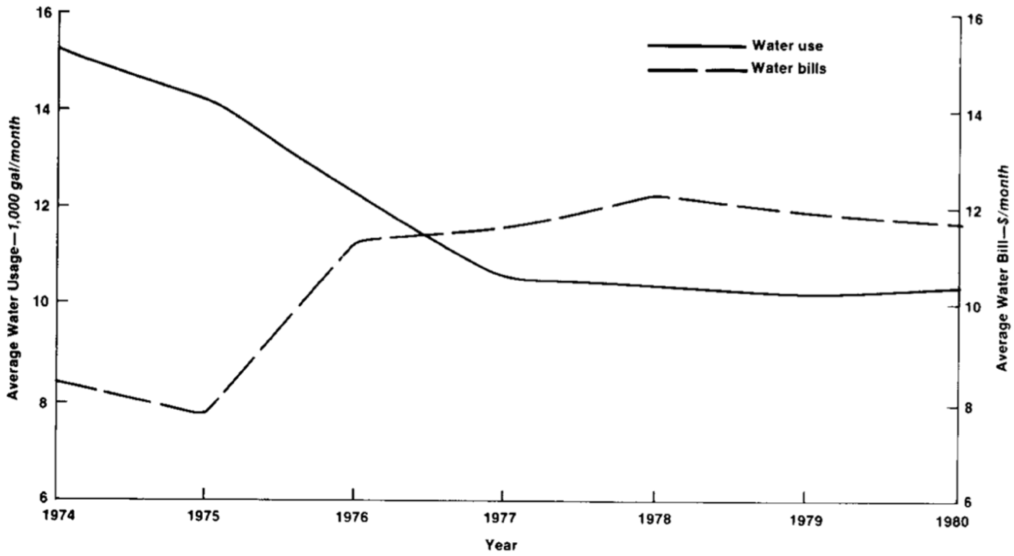

Figure 1: Average water use and average monthly bills of Tucson Water Department customers (Billings & Day 1989). The observation period covers years 1974 to 1980. A solid line in the graph represents the average water use in unit of 1000 gal/month and a dashed line represents the average amount of the water bill in unit $/month.

Billings & Day (1989) concluded that the water use is strongly influenced by the price, the income, and the socio-economic factors, while the public promotion for the need of conservation has a minor impact. The long-term price elasticity for this area is -0.72, for the availability-of-service charge –0.02, and for the marginal price -0.05. Based on these results, Billings & Day (1989) state that pricing equity can be improved, while promotion conservation, by increasing the marginal price rates, and decreasing the availability-of-serve charges (see also section 2.1.4). For the income, they calculated an elasticity of +0.33, which proves the significant impact of the variable on the consumption. The use of water is positively correlated with the income changes and differences (see also section 2.1.5). One of the socio-economic factors is home ownership with an elasticity of -0.18, which indicates that owners tend to be more water conserving (see also section 2.1.2). The analysis of different age groups showed that the consumption increases in the age group 65 and older (see also section 2.1.1.2). Another factor is the growth of the supply system and the development of residential areas, which have a negative relationship to water use. Publicity has, despite of the success in water conservation in Tucson, a very small impact in the models. The calculated elasticity is -0.05, because the effect just exists as long as the campaign is public. Billings & Day (1989) compared also the marginal and average price models, and concluded that the average price model shows a superior statistical strength for most of individual districts (e.g. high income areas and low water price areas), while the marginal model is superior for districts with particularly low income. In the end Billings & Day (1989) recommend that if officials require water use reduction in their district, water-conserving subdivision regulations are the most effective way for implementation.

2.3.3 Helsinki - Uusimaa - Finland (Ahopelto et al. 2015)

The study of "Forecasting water consumption for 2016-2035 (Vedenkulutuksen ennustaminen vuosille 2016-2035)" from 2015 was provided for the local water supplier, the Helsinki region environmental service authority (HSY) as a part of the course "*Mat-2.4177 - Seminar on Case Studies in Operations Research*" at the Aalto University, Helsinki. HSY supplies water for about one million people at the metropolitan region Helsinki, including the cities of Helsinki, Espoo, Vantaa, and Kauniainen. The population is estimated to grow about 19% until 2035 (Ahopelto et al. 2015).

The purpose of the study of Ahopelto et al. (2015) was to search for variables affecting residential water demand in HSYs' service area. The analysed variables that influenced the water consumption were plumbing renovations, family size and age, as well as the building age. The initial purpose was also to estimate how these variables are changing in the future and thus forecast water demand. This goal was not fulfilled. For the calculation, they used quantitative methods to fit the certain purposes of the analysis. The water consumption data was obtained from the billing information, which is based on the water meter readings form HSY. The information about the buildings, e.g. number of inhabitants, the age distribution, and businesses was obtained from the SeutuCD. It is a data collection done by HSY, with annual regional data from the municipalities. The data sets cover the periods of 2002-2003 and 2008 onwards. The last necessary information for the analysis is the development of the population in the region, which was published in 2015 by Helsinki Region Info Share (2015).

To analyse the variable plumbing renovation, a difference-in-differences–method, where the former and actual water consumptions of the building are compared, was used. For this part of the study, Ahopelto et al. (2015) used only four buildings renovated in the period 2007-2009. This sample size was too small to validate the results statistically, but the consumption was anyway lower for all buildings after renovations, on average 14%. Next, the influence of the family size was examined using two regression models in combination with least squares fitting. The first model is using an exponent function and the second a binary function, where all different family sizes were individual factors, to fit the regression for the data. Moreover, for this part of the analysis the data set was limited so, that just new single houses, built after 2005 and the water consumption of 2013 were included. The annual consumption for just one year was analysed to point out the effect of possible trends. The regression analysis showed that all coefficients of determination are very low. The first model gave a R^2 of 0.19. In the analysis of the influence of the family age, just the data for two-person households were considered. A regression model was used to evaluate the data. The results are significant but also very low with a R^2 of 0.02. The last factor was the building age, where the data was classified by the three different types of housing (single, row, and apartment). The regression analysis was performed for each type and concluded the fitting of single houses with R^2= 0.004, row houses with R^2= 0.012, and apartment houses with R^2= 0.054.

2.3.4 Hanseatic city of Hamburg – Germany (Kluge et al. 2014)

In their study, Kluge et al. (2014) created a water demand forecast until 2045 for all consumer types in the metropolitan region of Hamburg. Aim is to support the future technical and economic decisions of the water company of Hamburg Ltd (HWW). The local water supplier HWW supplies the seven city districts and thirty surrounding communities of the free and Hanseatic city Hamburg with water. In 2011, HWW supplied 2,060,000 people in total with 108,767,598 m^3, from which 13% lived in the surrounding area. Around 76 M m^3 (69,7%) of the total water consumption are consumed for domestic use. The summary in this subsection is focused on the residential water consumption.

Kluge et al. (2014) analysed in their study the specific water consumption until 2045 by including factors such as population growth, technical developments, and the consumption behaviour of the customers. The importance of the study is based on the fact that the predominant trend since 1970s' was an ongoing decrease of the water supply, while the population has increased. However, in 2007 first signs for a consolidation of this supply trend was observed due to an ongoing population growth. Since 2007, the specific water consumption, including all customer types, decreased from 200 L/cap/d to under 140 L/cap/d.

The concept is mainly a mix methods approach to fit the specific purposes of the analysis. The analysis starts with a sub spatial analysis to provide necessary information about the settlement structure as well as the social and technical differences in the districts. In addition to that, statistical analysis (e.g. for population growth), special surveys (e.g. technical features of the households), and expert talks and interviews (e.g. concept for housing development), were used to model the future changes of those observed categories. All this information is included in the forecast of the water consumption using five different scenarios. The first one is a reference scenario based on the census data from 2011, the second is using the population growth based on housing development plans, natural population development, and migration, the third is focused on climate change, the fourth on saving behaviour and technical development, and the fifth on the population growth with housing development.

Kluge et al. (2014) detected for the first scenario that the total water consumption in the 103 quarters of Hamburg is developing quite divergently (Figure 2). In six of the quarters (marked green) the consumption increase by more than 25,000 m^3/a, in 45 of the quarters (marked yellow) just small changes were determined, and in the remaining 52 quarters consumption decrease by more than 25,000 m^3/a. According to this scenario, 65% of the quarters have already reached their maximum in demand in 2011, and afterwards there will be a steady decrease.

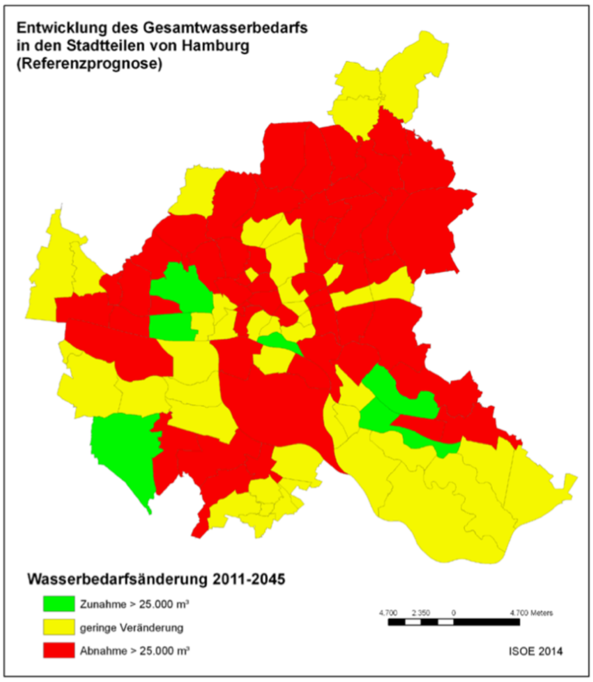

Figure 2: Forecast of development of the total water supply according to the reference scenario in all city districts of Hamburg between the initial year 2011 and the forecast year 2045 (Kluge et al. 2014). The map presents all 103 city districts. Red color indicates districts where the consumption decrease by more than 25,000 m^3/a, yellow indicates districts where the consumption is subjected to minor changes, and green indicates districts where the consumption to increase over 25,000 m^3/a.

The result for the second scenario showed a nearly steady consumption development in the city until 2045. Therefore, the consumption in the communities decreases by 0.5 M m^3/a. Because of the climate change, the daily average consumption is increasing by around 0.4%. During the summer months' increase is around 1%, while the average daily consumption decreases during the winter months by around 0.2%. The biggest influence has the fourth scenario. Because of the saving behaviour and efficient technical devices, the needed for the residents decrease by 7.5% until 2045. In the communities, decrease is with 10.8% even higher. This means for the total consumption a decrease by 7.1%, down to a consumption of 101.9 M m^3/a. The last scenario is influenced by the high dynamics of the housing development in the next 10 to 15 years. Therefore, the residential water demand in the city is increasing by 2.3%, up to 69.5 M m^3 in 2025. A summary of the changes of the raw water quantity[2], by using the presented scenarios for the forecast, is presented in table 4.

Table 4: Comparison of the raw water quantity in 2011 and 2045 for all performed scenarios (Kluge et al. 2014)

Scenario	**Raw water quantity [m^3/a]**	
	2011	2045
Reference	117,620,731	114,518,818
Population option 1	117,620,731	116,061,937
Climate change	117,620,731	114,740,607
Saving behaviour + technical development	117,620,731	110,028,451
Population option 2	117,620,731	118,519,899

[2] Includes consumption households, economy, redistributors, other customer groups, the subsistence's of HWW and piping losses.

3 DATA & METHODS

The study required data from the water utilities as well as from the local resident registration authorities and the building authorities. Some parts of the necessary data were difficult to obtain, incomplete or non-existent, which influenced the possible determinable research frame. The water consumption was calculated using the unit water demand analysis. The development of the consumption was calculated for the influencing factors population age, household size, building age, water meter type, and income. The following sections summarises the used data provided by the HSY and HWW, as well as the data gathered through research from pages of other authorities. Moreover, the used mix method approach using the provided data is explained.

3.1 Data

The provided data information varied between the suppliers, and based on this it was not possible to perform the detailed analysis for Hamburg. The used data components are explained more in detail in the following sections.

3.1.1 Water Consumption

The input data for the water consumption analysis of the metropolitan region Helsinki was provided by HSY. It is based on the billing information for the years 2004 until 2014 of each building or property in the supply districts Espoo (049)[3], Helsinki (091), Vantaa (092), and Kauniainen (235). These data sets include spatial coordinates (Karttakoordinaatit itäinen/pohjoinen) and an individual ID for each water meter. The data was provided as Excel-sheet for each year. The reading of the meters does not take place at the same time each year. Therefore, the provided water consumptions are derived estimates of the yearly consumption. The analysis is focused on the residential water consumption, hence just the demand of the residential buildings (blocks (Kerrostalo), single-family houses (Omakoti- tai paritalo), and terrace houses (Rivi- tai ketjutalo)) was used.

[3] The number in parentheses is the municipality code (Kunta tunnus) of each city.

Moreover, the input data for the water consumption analysis of the Hanseatic city of Hamburg was provided by HWW. The total discharge, the water price, and the basic price for the years 2004 until 2015 was provided as an Excel-sheet.

3.1.2 Population

The input data for the population of the metropolitan region Helsinki was also provided by HSY for the years 1997 until 2003 and from 2008 until 2015. Population data is from the SeutuCD, which is a database containing information about population, buildings, and businesses of the supply area. The data were gather in Excel-sheets by HSY on a yearly basis for each building. The population per building (ASYHT-Asukkaat yhteensä) and the average age per household (IKA_KA-Ikäkeskiarvo) were used from the population data sheets. Those data sheets were also used to analyse the consumption depending on the household size, by using the amount of people per house. To provide reliable results for both analysis just the single-family houses (Omakoti- tai paritalo) were used.

The population data of the districts of the Hanseatic city of Hamburg were available on the webpage of the Northern Statistical Office for the years 2008 until 2016 (Northern Statistical Office 2016). The data includes the population, the amount of people under 18 and over 65 years[4], the number of foreigners, the space in km^2, and the population density. The gathered data were just used for the analysis of the development of the residential water consumption per person. The missing population data from 2004 until 2007 was gathered from the internet (Northern Statistical Office 2009; Northern Statistical Office 2011; Northern Statistical Office 2015; Northern Statistical Office 2016).

3.1.3 Buildings

As mentioned in the previous section, also the building data was provided by HSY and gathered from the SeutuCD as Excel-sheets. The data covers the years 1997 until 2003 and 2008 until 2015. The building year (KAVU-Käyttöönottovuosi) was used for the calculation of the demand depending on the building age of the house, and the analysis of the consumption differences depending on the billing based on a common or individual water meter.

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[4] The age of 18 is the age where people reach majority and 65 is the actual retirement age in Germany.

3.1.4 Income Level

The average income per year of the Helsinki city districts was available at the webpage of Helsinki Region Infoshare for the years 2004 until 2014 (Helsinki region n.d.). The research area for the income analysis was reduced, as the average income data was available for the city of Helsinki. For the analysis of the water consumption influenced by the income, both available data possibilities, on large district level (suurpiiri), and small district level (peruspiiri), were used. To connect those input data with the population data, the district code (KOKOTUN-Yhdistetty aluetunnus), and a district shape-file for the city Helsinki were used. To improve the presentation format of the analysis on the small district level (peruspiiri), ten income categories were set. The defined income categories are a yearly income <20,000 €/cap/a, 20,000-22,499 €/cap/a, 22,500-25,999 €/cap/a, 25,000-29,999 €/cap/a, 30,000-34,999 €/cap/a, 35,000-44,999 €/cap/a, 45,000-54,999 €/cap/a, 55.000-74.999 €/cap/a, 75,000-99,999 €/cap/a, and ≥100.000 €/cap/a.

3.1.5 Forecast Data

The forecast input data were gathered from three different forecast reports for Helsinki, Espoo, and Vantaa. In Kauniainen, the population is only around 10,000 inhabitants. Water demand of Kauniainen is not greatly affecting the future water demand of the study area, so therefore it was excluded from the forecast. The population development was necessary for the forecast as the future demand was calculated according to the future population (see section 3.3.3). The forecast for Helsinki was divided in two parts. First, the demand for the districts (suurpiiri) was forecasted until 2025, and then for the whole city until 2050. This was based on the population forecast from the report "Population forecast for Helsinki and Helsinki region 2016-2050 (Helsingin ja Helsingin Seudun Väestöennuste 2016–2050)" (Vuori & Laakso 2016). For Espoo, the future demand was calculated until 2050 based on the population development from the report "Population projections for Espoo and Helsinki Region 2015-2050 (Espoon kaupungin ja Helsingin seudun väestöprojektiot 2015-2050)" (Laakso & Kilpeläinen 2015), and for Vantaa until 2040 based on the report "Population forecast for Vantaa 2016-2040 (Vantaan väestöennuste 2016-2040)" (Manninen 2016). As the population forecast for Vantaa was just available until 2040, the analysis about consumption development of the metropolitan region Helsinki was done until 2040.

3.1.6 Plausibility and Correction of the Data

The data sets have partly a lack of information. To be able to work with the data sets, some research, assumptions, and calculations were done. The from HWW provided data included, inter alia, the total discharge. Therefore the share of 69.7% of the total water consumption was used to obtain the residential water consumption (Kluge et al. 2014). The assumption was that the share on the total water consumption is the same for the whole observation period. This assumption can cause some errors for the results, as the share of the residential water consumption is variating over the time. However, the study period is so short that this variation can be neglected.

The population data includes the number of people of each age in the house, but this kind of information was not usable for the analysis, as the consumption was provided per building and the individual use of each person was not available. Thus, to avoid preventable mistakes the average age of people in the property was used to analyse the consumption of each age group. The maximum was set at 14 people per household as some of the properties, marked as single-family houses, had an unrealistic number of e.g. 30 inhabitants per household.

The building data have a lack of information, as the renovation status is not available in the data. Through research from the webpage of the Finnish brokerage Oikotie, extra information about the renovation status was gathered (Oikotie n.d.). According to the webpage, most of the buildings, built in the 80s' were renovated by now. Though, it was unknown what exactly have been renovated in each case. Therefore, this information from Oikotie is not 100% reliable. Nevertheless, this information was one indicator for the setting of the analysis time periods. In addition to that, the lack of information about the usage and installation of individual water meters was a problem for the analysis of the influence of the water meter type. The Finnish law determines that individual meters must be installed in houses built from 2011 onward (see section 2.1.3). However, property owner still has the right to choose, if they bill based on individual water meter, and if they install individual water meter in house built before 2011. Due to the lack of information, the assumption that all buildings after 2010 are billed based on their meter consumption, was made.

Another problem was that the data sets are not complete for each observed period. For the analysis of the development of the residential water consumption per person, population data from the internet was used (UNdata 2017; City Population 2017). The reason was that the calculated number of inhabitants differs from the official number of inhabitants. As an example, the number of inhabitants calculated using the data was 860,614 in 2004, while the published number of inhabitants was 978,369 (UNdata 2017; City Population 2017). All additional data sets as population, and building information were missing for the years 2004 to 2007. For Kauniainen the population, and building information was also missing for 2008 and 2009. To bypass this data gap, the needed information was generated using linear interpolation between the years 2003 and 2008. In addition, Kauniainen was decided to be excluded from all the analysis. Before the data preparation process, the plausibility of the data was checked.

Moreover, some households have a negative or an extremely low consumption. Therefore, all consumptions under 30 M m^3/a were excluded from the data sets until 2008, and from 2009 onward all consumptions under 25 M m^3/a. This is possible because some of the connected houses may be just cottages (Mökki) or allotment gardens, which are not in use full-time. To decrease the possible error, half of the average consumption per person in a year was used as the lower limit value for representing a realistic consumption.

3.1.7 Residential Water Consumption

The total residential water consumption was calculated to see the yearly trend. It was done for the metropolitan region Helsinki and Hamburg. It was performed in two different ways. First by calculating the total residential consumption (M m^3/a) and then the average consumption (L/cap/d). The provided water consumption tables needed to be edited before the creation of the property code (KIITUN- Kiinteistötunnus) (see appendix 1). By deleting the rows without 1-4-digit numbers, the calculated total residential consumption was lower. This was observed through the calculation and comparison of both calculated consumptions (Table 5). Therefore, the original billing data table, not the edited one, was used to calculate the residential water consumption of Helsinki.

Table 5: Comparison of the residential water consumption based on the input data

M m^3/a	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Original	52.06	52.31	52.92	52.24	52.15	50.03	49.80	48.82	48.12	46.76	46.56
Edited	50.47	50.66	51.10	50.53	50.05	50.01	48.56	47.50	46.89	45.49	45.37

As mentioned in section 3.1.6, the data gap for Hamburg was bypassed using the information about the percentage of the residential consumption from the total consumption. The consumption per person and per day was calculated for Hamburg according to the total residential consumption, and for Helsinki according to the housing type. The aim was to gather some information about the yearly trend of the consumption. Both data were saved in a new Excel-sheet, and displayed as a graph. The results are presented and evaluated in section 4.1.1.

3.2 Software

Based on the lack of data, all the factors, which were found to have influence on the water consumption in the theoretical part, were not able to be modelled. As already mentioned, for the Hanseatic city of Hamburg none of the chosen influencing factors were analysed. As a specific model requires a lot of knowledge and long enough data series, a mix methods approach was the best solution to estimate the consumption under different aspects. The mix methods approach allows the use of multiple methods and different software programs to address the study objectives (Willis, Stewart, Giurco, et al. 2011). A further explanation about the used programs are presented in the following sections.

3.2.1 Microsoft Excel

As the main data were provided as Excel-sheets, Microsoft Excel was always used to prepare the tables before and after certain modifications with ArcGIS, and before running the analysis with MATLAB. Moreover, all results were saved as Excel-sheets, which makes the presentation of the tables and the exchange of the information with further studies less complicated. Furthermore, Excel was used for creating the forecast for Helsinki.

3.2.2 ArcGIS

All the data from HSY include coordinates for each property, which made it possible to use ArcGIS as an interface for the analysis. By converting the tables into a shape-file, it was possible to display the data, check their reliability, and do relevant corrections if necessary. The reliability was also double-checked using ArcGIS attribute tables. With the ArcGIS data management tool JOINS, it was possible to create tables for the analysis, which include all the necessary information (water consumption, population, and building information). Joining the different data together was done by connecting the single tables by a common attribute with the result of a new attribute table. The new attribute table included just information of those properties for which a consumption was recorded. This was done for the whole analysed period (2004-2014) and each city of the metropolitan region Helsinki (Espoo, Helsinki, Vantaa, and Kauniainen). Subsequently, it was also possible to convert the created shape-files back into an Excel-format by using the ArcGIS Conversion tool TABLE TO EXCEL.

3.2.3 MATLAB

The main part of the analysis was done with MATLAB. The calculations were realized by building a MATLAB-code according to the analysis purpose. MATLAB was also used to create the missing property code (KIITUN) for the water consumption data, and to remove the doubled data from the new created tables. An error was created through the usage of the property code to join the water consumption data with the other input data. Sometimes property (KIITUN-Kiinteistötunnus) includes multiple buildings (RAKTUN-Rakennustunnus), which are all metered together. Therefore, in some cases, the buildings (RAKTUN) with the same property code (KIITUN) were allocated the same metered value, which falsified the first results. Based on this it was necessary to summarise those building together on property level. In this way, the error of using one consumption two times was eliminated.

3.3 Methods

As already mentioned in section 3.2, a mix methods approach and three different software types, were used for this work. The implementation process consists of four main steps, which are data preparation, analysis, statistical evaluation, and forecast. Those steps are explained more in detail in the following subsections.

3.3.1 Analysis

Based on the provided input data the choice was to analyse five out of the eight influencing factors discussed in the theoretical part. Influence of the age of the tenants, the household size, the age of the building, the billing based on an individual water meter, and the income on the residential consumption were analysed. The analysed buildings were residential buildings: single-family houses (Omakoti- tai paritalo), terrace houses (Rivi- tai ketjutalo), and blocks (Kerrostalo). The main approach started with the data preparation by using Excel and ArcGIS (see appendix 1), followed by dividing the data according to the research purpose, and ended with the calculation of the consumptions. This approach was almost the same for each analysis. According to their purpose and the provided input data, the used data and their preparation, and handling for the analysis was done a bit different. The results for all groups and years were saved in new Excel-sheets, and displayed as a graph. The detailed explanation is presented in the following section.

3.3.1.1 Water Demand – Average Age of the Household

The aim of this analysis as to figure out if retired people or families with children or teenagers are the higher water consumers in the metropolitan region Helsinki. The main purpose for this was that the water consumption is influenced by the personal phase of life, so attempts were made to reflect those life phases through the defined groups (see section 2.1.1.2). For the analysis, the following groups of ages were defined: ≤25, 26-30, 31-45, 46-50, 51-68, and ≥68. As an example, the retirement age in Finland is between 63 and 68 (Finnish Center for Pensions 2017), therefore the last boundary was set at the age of 68, with the intention to see if retirement affects the water consumption in this supply area. The consumptions of each person belonging to the household were not available, even if the amount of people of each age was available. Just all single houses were involved to the analysis, and so it was possible to use the average age. It was then possible to say that, if the average age was quite low, the household includes one or more young children, and if it was high, the household includes old, and already retired people. Through this assumption, the main purpose of this analyse can be still fulfilled. The results are presented and explained in section 4.1.2.

3.3.1.2 Water Demand – Household Size

The purpose of this analysis of the household size was to figure out the consumption behaviour of smaller or bigger households. Since smaller households generally consume more water per person compared to those with a bigger number of inhabitants (see section 2.1.1.1), the groups were chosen so that single households and two-person-households were each a single group. For the analysis, the following groups were defined: 1 inhabitant, 2 inhabitants, 3-4 inhabitants, 5-6 inhabitants, 7-10 inhabitants, and 11-14 inhabitants. Furthermore, the original input data were not that suitable for this analysis (see section 3.1.6), so the same prepared data sets were used than for the age analysis. For a better reliability of the results, it was better to include just the single-family houses, because the inhabitants of a single-family house can be assumed equal to the household size. The number of inhabitants of terrace houses (include more than one house) or blocks (include multiple number of flats) does not represent the household size, therefore those two building types were excluded from this analysis. Those housing types can be just included if the consumptions of individual meters are provided. The results are presented, and explained in section 4.1.3.

3.3.1.3 Water Demand – Building Age

The intention behind this analysis was to analysis if people living in old buildings are the higher water consumer, and if a decrease in consumption through renovation processes is visible. This time all residential housing types were included in the calculations. The consumption was analysed for the buildings built between 1900 and 1949, 1950 and 1964, 1965 and 1979, 1980 and 1989, 1990 and 1999, as well as between 2000 and 2014. The dividing of the groups was influenced by the research done from the Oikotie webpage (see section 3.1.3). The houses built after 2000 were defined as the new buildings, with the most recent technologies. Therefore, in the new buildings the water consumption levels should be the lowest as well as in the buildings constructed in the 80s'. Before running the code, all consumptions under 30 M m^3/a until 2008, and under 25 M m^3/a from 2009 onward, were deleted from the data sets. The principle of the MATLAB code was again the same as for the ones before (see annex 2).

Another analysis based on the calculated data was also made to support the results of the consumption depending on the age of the inhabitants. The aim was to check if there is maybe another reason behind the higher water consumption of older people. Therefore, consumption depending on the building age was connected to the average age of the residents of those buildings. This means that in addition to the consumption, the average age of each group was also calculated with the same MATLAB code. The results are presented and evaluated in section 4.1.2, and 4.1.4.

3.3.1.4 Water Demand – Water Meter

The purpose of the analysis of the differences of the water consumption depending on a common or individual water meter was to identify if the installation of individual meters since 2011 does already show any effects. According to the literature, the usage of induvial meters decreases the water consumption (see section 2.1.3). For the analysis, the following groups were defined: 1980-1989, 1990-1999, 2000-2010, and built after 2011. According to the research, most of the buildings built in the 80s' were renovated by now, and therefore might have already individual meters. Single-family houses are already equipped with individual meter therefore they were excluded from this analysis. The reason is that there were not any changes through the law changes since 2011 (see section 2.1.3). The period for the analysis was reduced from 2004 until 2014 to 2011 until 2014, also based on the regulation. No individual meters need to be installed before 2011, therefore an observation of the consumption in the years before would not have made sense for this purpose. It was already mentioned earlier that one big problem was the lack of information about the renovation status (see section 3.1.3), that led to the assumption that all blocks and terrace houses with the building year 2011 and later, are equipped with individual meters.

To check the reliability of the analysis results, a smaller analysis was performed using Excel. Information was gathered for four of the buildings from the Oikotie webpage. Buildings were selected so that they are equipped with individual meters and all of them are blocks. Two of the listed buildings were new buildings and two were renovated ones, originally built in the 60s'. The blocks were searched using their building code (RAKTUN), and after that their total consumption per year as well as the number of residents (ASYHT) for the years 2010 until 2014 were stored in a new Excel-sheet. The number of residents was displayed in the graph too, with the goal to be able to explain results better. Both results are presented and explained in section 4.1.5.

3.3.1.5 Water Demand – Income

The aim of this analysis was to see if there is a connection between income and the water consumption of a person in the research area. According to the literature, the income just influences the water consumption if the costumers are billed based on their own consumption (see section 2.1.5). Therefore, just three years were selected, with the intension to see a difference through the law change. Based on the income data gathered through research (see section 3.1.4), this analysis was performed just for the city of Helsinki. The observed years were 2008, 2011, and 2014. Moreover, all smaller districts (peruspiiri) belonging to Östersundom were excluded from the input data, as this district is not supplied by HSY[5]. There were two ways to display the analysis output. The first option was to use the bigger districts (suurpiiri), and the second to define income groups based on the average income (€/cap/a) in the smaller city districts (peruspiiri). The listing of the allocation of the districts is given in table 6.

Furthermore, the districts were allocated to the ten defined income groups, which were a yearly income <20,000 €/cap/a, 20,000-22,499 €/cap/a, 22,500-25,999 €/cap/a, 25,000-29,999

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5 Information gathered during the meeting with HSY and Riina Liikanen on the 12th of May at the Vesilaitosyhdystys (VVY) office, Ratamestarinkatu7 B, 00520 Helsinki.

€/cap/a, 30,000-34,999 €/cap/a, 35,000-44,999 €/cap/a, 45,000-54,999 €/cap/a, 55.000-74.999 €/cap/a, 75,000-99,999 €/cap/a, and ≥100.000 €/cap/a.

Table 6: Overview of the allocation of the districts (Tikkanen & Selander 2014)

091 1	091 2	091 3	091 4	091 5	091 6	091 7
Eteläinen suurpiiri	Läntinen suurpiiri	Keskinen suurpiiri	Pohjoinen suurpiiri	Koillinen suurpiiri	Kaakkoinen suurpiiri	Itäinen suurpiiri
Vironniemi	Reijola	Kallio	Maunula	Latokartano	Kulosaari	Vartiokylä
Ullanlinna	Munkkiniemi	Alppiharju	Länsi-Pakila	Pukinmäki	Herttoniemi	Myllypuro
Kampinmalmi	Haaga	Vallila	Tuomarinkylä	Malmi	Laajasalo	Mellunkylä
Taka-Töölö	Pitäjänmäki	Pasila - Böle	Oulunkylä	Suutarila		Vuosaari
Lauttasaari	Kaarela	Vanhakaupunki	Itä-Pakila	Puistola		
				Jakomäki		

By using the code for the bigger district (Table 6, first row) and the district code, the smaller districts (peruspiiri) were assigned to their income group. This was done in Excel with the filter tool, and by adding a new column with the district code, and one with the district name. Both results are presented and explained in section 4.1.6.

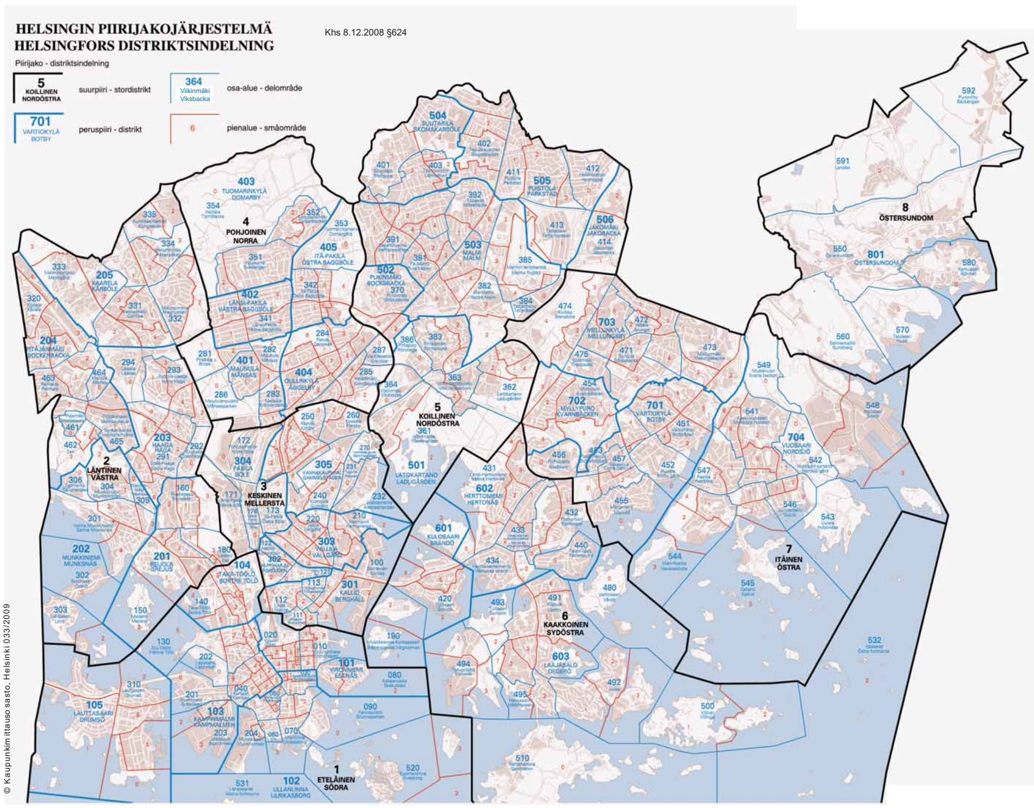

Figure 3: Map showing the Helsinki districts on the big district level (suurpiiri) and the small district level (peruspiiri) (City of Helsinki 2008). The eight major districts of Helsinki have thick black borderlines, the smaller districts have thick light blue borderlines, the quarters (oas-alue) have the thin light blue borderlines, and the sectors (pienalue) have light red borderlines.

3.3.2 Statistical Evaluation

To evaluate the reliability of the data, it was necessary to carry out a statistical evaluation of the results. The easiest way was to estimate the linear trend in the data (Formula 3). The assumption of a linear regression analysis is that there is a dependence or causal relationship between one or more independent variables and one dependent variable (Statistics Solutions n.d.). Regression estimates, where y is the estimated dependent score, c is a constant, b is the regression coefficient, and x the independent variable, were used to explain the relationship between one dependent variable and one or more independent variables (Statistics Solutions n.d.). The dependent variable is the prognostic variable and the independent variable is the predictor variable (Statistics Solutions n.d.). This was conducted with MATLAB, by using the fitlm-function.

$$y=c+b*x \qquad \textit{Formula 3}$$

As an example, in case of testing the reliability of the results for the residential water consumption the x-value represents the years, and y-value the water consumption values. The function returns a linear model fitted to the variables. For the other analysis, the only difference was that the time steps (e.g. 2004-2014) are used as the x-values. Based on this, each defined group was evaluated over this time span. The evaluation results regarding the main results for each analysis are presented and explained the sections 4.1.1-4.1.6.

3.3.3 Forecast

After choosing the factors with an influence on the water consumption, it was possible to include them in the forecast, to calculate a more accurate demand in the future. In this forecast performed with Excel, just the influence depending on the building age was possible to be included. To be able to include the analysis results in the forecast, the assumption was that all new people are living in new houses[6]. Observed was the future consumption in the city districts of Helsinki (suurpiiri) until 2025, in the cities Espoo and Helsinki until 2050, in Vantaa until 2040, as well as in the metropolitan region until 2040. Forecast was based on the consumption results from 2014, and the population forecasts from the observed areas (see section

[6] In this case, all houses built in and after 2010 were defined as the new houses.

3.1.5). To implement the two forecast versions, which will be explained in the following chapters, it was necessary to create a data input set. This was done by using the original input data and the converted data to gather necessary information as the district code, the building year, the number of people, and the average consumption per person and day.

First, the total consumption as well as the average consumption (L/cap/d) of all, and just of the new buildings were calculated, based on the converted data sets from 2014. Because in each district, the number of included new households was considered too small to achieve reliable results, the rule of three was used to calculate those values. The original data set was needed because the calculated consumptions, based on the converted data sets, is too low. The procedure was the same for all, except for the per person consumption. Because of the missing population information in those data sets, the consumption was also calculated using the rule of three. The population data start in 2013 and continue as long as data for the overserved district or city is available. The calculated consumptions based on the original data was chosen as a start value. The start value for the consumption in unit of L/cap/d was calculated based on the population input data from the forecast reports for this year.

3.3.3.1 Forecast First Version

The main assumption of this forecast version was that all inhabitants always use the same amount as in the year before. The implementation approach is given in formula 4 to formula 7. The total consumptions in unit of M m^3/a (V_t), and unit of L/cap/d (v_t) were calculated with the following two formulas:

$$V_t = \left(\frac{(v_{t-1} * pop_t) * 365}{1000000000}\right) * V_{t,new} \qquad \textit{Formula 4}$$

$$v_t = \left(\frac{\left(\frac{V_t}{pop_t}\right)}{365}\right) * 1000000000 \qquad \textit{Formula 5}$$

To calculate the consumption in unit of M m^3/a ($V_{t,new}$), and unit of L/cap/d ($v_{t,new}$) for the new houses the following formulas were used:

$$V_{t,new} = \left(\frac{\left((pop_{t,new} - pop_{t-1,new}) * v_{t-1,new}\right)}{1000000000}\right) * 365 \qquad \textit{Formula 6}$$

$$v_{t,new} = v_{t-1,new} - (v_{t-1} - v_t) \qquad \textit{Formula 7}$$

The forecast results, with this method were saved in a detached Excel-sheet and displayed in a graph. All results are presented and explained in sections 4.2.1, and 4.2.2.

3.3.3.2 Forecast Second Version

This second forecast of the consumption development was using intermediary steps. The intermediary steps are kind of interpolation steps between the years, and they were used to enable the calculation of the consumptions of the old population and the new population separated from each other. The main assumption was the same, but implemented in a different way (Formula 8). The consumption in unit of L/cap/d (v_i) for the starting point of the intermediary steps was calculated with the population data from 2013. The following years were calculated based on the rule of three.

$$V_i = V_t - V_{t,neu} \qquad \textit{Formula 8}$$

The total consumption in unit of L/cap/d (v_t) was calculated as in formula 5, while the total consumption (V_t) was calculated using the following formula:

$$V_t = \left(\frac{(v_i * pop_{t-1}) * 365}{1000000000}\right) + V_{t,new} \qquad \textit{Formula 9}$$

Due to the complex calculations, the formula 10 and formula 11 display the calculation path.

$$V_{i,new} = \left(\frac{v_{t-1,new} * pop_{t-1,new}}{1000000000}\right) * 365 \qquad \textit{Formula 10}$$

$$v_{i,new} = \left(\frac{\left(\frac{V_{i,new}}{pop_t}\right)}{365}\right) * 1000000000 \qquad \textit{Formula 11}$$

The total consumption ($V_{t,new}$) for the new houses was calculated as in formula 6, while the consumption in unit of L/cap/d ($v_{t,new}$) was calculated with the following formula:

$$v_{t,new} = v_{t-1,new} - v_{i,new} \qquad \textit{Formula 12}$$

The forecast results with this method were saved in a detached Excel-sheet and displayed in a graph. All results are presented, and explained in sections 4.2.1, and 4.2.2.

4 RESULTS AND STATISTICAL EVALUATION

The analysis, statistical evaluation, and the forecast results are presented in the following sections. An overview of the statistical results can be found in appendix 8. The discussion about the significance, reliability, possible uses, and connection to other studies can be found in the following section 5.

4.1 Statistical Evaluation of the Historical Trend

The main part of this work is the analysis of the influencing factors on the past water consumption. The purpose is to use this knowledge for the implementation into the forecast. In the following subsections, the results, the calculated statistical R^2-values, and the p-value are presented.

4.1.1 Residential Water Consumption

First, the historical trend of the residential water consumption was evaluated. Figure 4 shows that the total consumption in Hamburg (light blue) was 77.02 M m^3/a in 2014 and in Helsinki (stocked bars) 46.57 M m^3/a. Concerning the consumption data from Helsinki, the portion of water used by every type of housing can be defined. The consumption in the blocks (yellow) were the greatest portion of the residential water consumption. In 2004, the total consumption was 38.43 M m^3/a in the blocks (yellow), which was 73.80% of the total residential consumption. The total consumption in single-family houses (green) was 7.10 M m^3/a, which was 13.63% of the total residential consumption, and the consumption in the terrace houses (dark blue) was 6.54 M m^3/a, which was 12.56% of the total residential consumption. Then in 2014, the total consumption was 32.51 M m^3/a in the blocks (yellow), which was 69.81% of the total residential consumption. The total consumption in single-family houses (green) was 7.71 M m^3/a, which was 16.55% of the total residential consumption, and the consumption in the terrace houses (dark blue) was 6.35 M m^3/a, which was 13.63% of the total residential consumption. The changes in consumption between years 2004 and 2014 in single-family houses (green), and terrace houses (dark blue) were quite low compared to the decrease in consumption in the blocks (yellow).

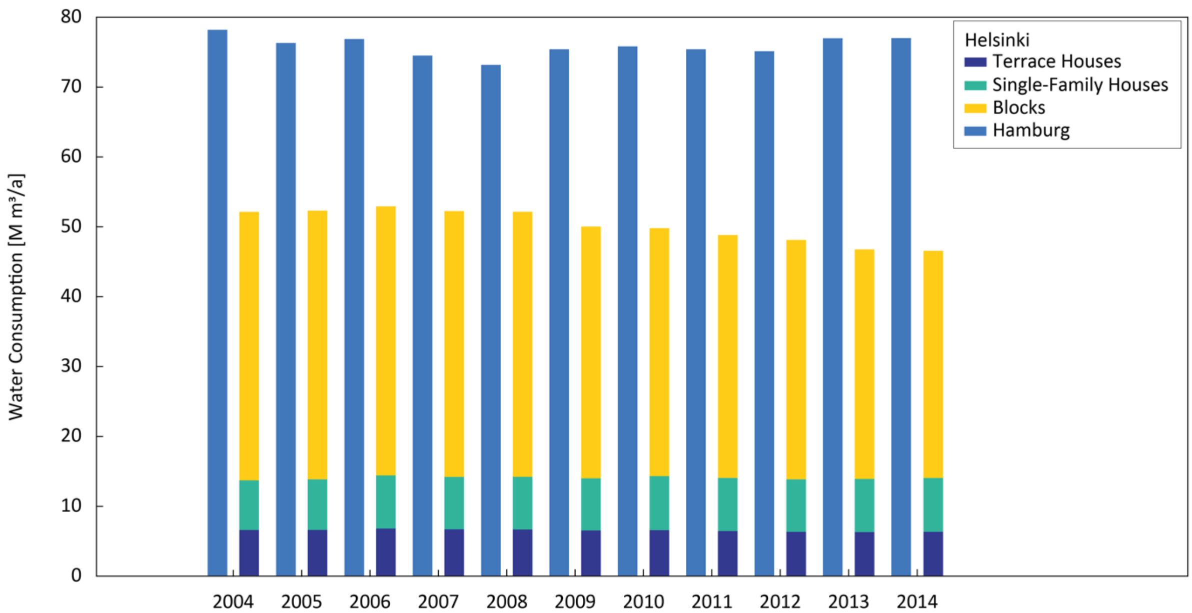

Figure 4: Comparison of the development of the total residential consumption (M m^3/a) in Helsinki (stocked bars) and Hamburg during the period 2004-2014. The consumption in Helsinki is divided into the three residential housing types. Yellow indicates the consumption for the blocks, green for the single-family houses, and dark blue for the terrace houses. The consumption in Hamburg is presented as a total consumption, indicated by light blue bars. Each bar represents consumption for one year during the observation period.

In total the consumption decrease was 5.50 M m^3/a, while the consumption decrease in the blocks (yellow) was 5.92 M m^3/a. In the single-family houses (green) increase was 0.61 M m^3/a, and in the terrace houses (blue) decrease was 0,19 M m^3/a. It can be seen that the decrease of the consumption was mainly influence by the consumption decrease in the blocks.

Additionally, the per person consumption of both cities was compared (Figure 5). A look on the individual consumption of the population until 2012 shows that consumption in Helsinki (dark blue) was 123.51 L/cap/d, and in Hamburg (light blue) 115.42 L/cap/d. So, consumption in 2012 in Helsinki was higher than in Hamburg. In 2013, the consumption in both cities was almost the same, 118.15 L/cap/d in Helsinki, and 118.27 L/cap/d in Hamburg. Then results for 2014 showed that the consumption in Helsinki was 115.85 L/cap/d, and in Hamburg 118.31 L/cap/d. This increasing trend in Hamburg will probably continue like this according to the forecast for Hamburg (see section 2.3.4).

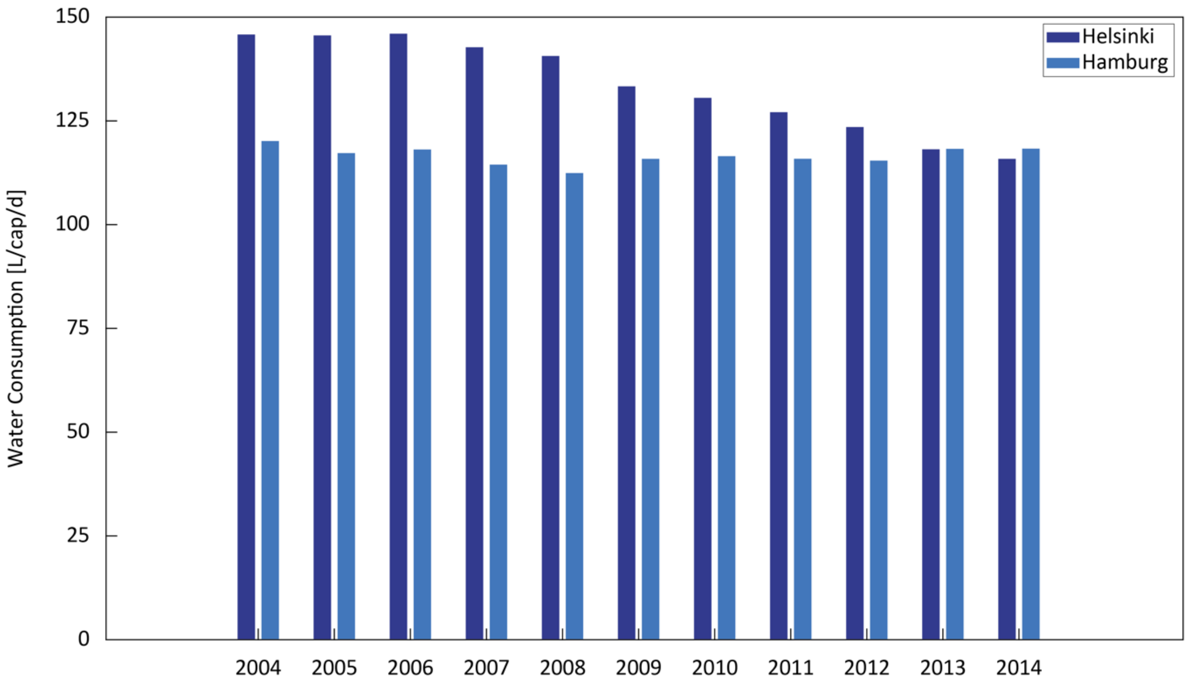

Figure 5: Comparison of the development of the residential per person consumption (L/cap/d) in Helsinki and Hamburg during the period 2004-2014. The average daily residential consumption per person in Helsinki is presented by dark blue bars, and in Hamburg by light blue bars.

For the historical trend evaluation, the linear trend of the data was calculated. To achieve a good fit, the p-value must be close to zero, and the R^2 close to one. Therefore, a linear trend was fitted to the consumption data. The graphs in figure 6 shows that, the total consumption, and residential per person consumption in Helsinki had a strong linear trend, while in Hamburg there was no linear trend. This was also seen from the p-value and R^2-value.

The resulting p-value for Helsinki was 0.00001, and the R^2 0.89186. For the data from Hamburg the p-value was 0.79738, and the R^2 0.00771.

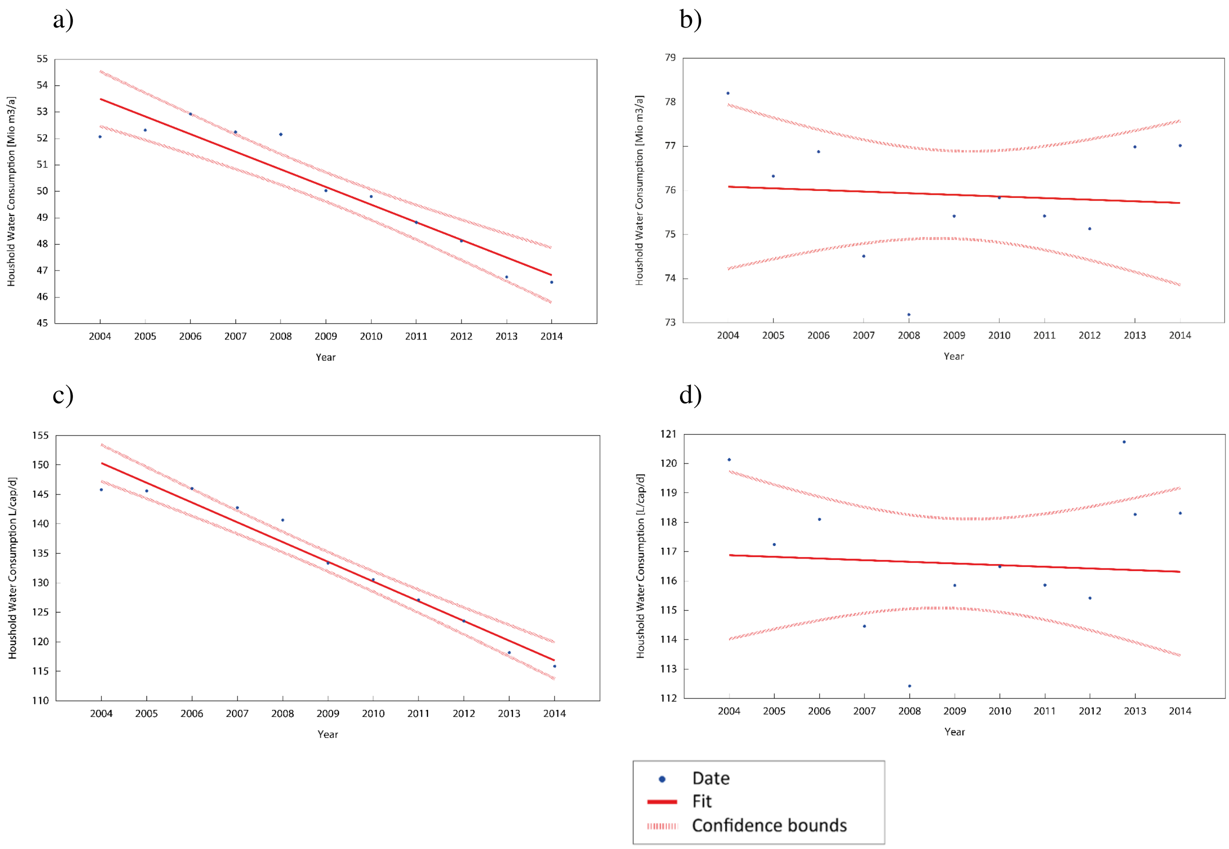

Figure 6: Linear trend in the household water consumption in Helsinki (left) and Hamburg (right). Pictures are marked with letters: a) and b) total consumption, and c) and d) per person consumption. The blue crosses are the data points, the red solid line indicates the linear trend in the data, and the dashed red lines indicate the boarders of the confidence interval.

4.1.2 Water Demand – Average Age of the Household

The water demand depending on the average age of the household residents (Figure 7), showed clearly that in 2014 older people (≥68, yellow bar) consumed 143.61 L/cap/d of water, while consumption of younger people (≤25, dark blue bar) was les, 109.43 L/cap/d. The consumption of the group with an average household age between 46 and 50 supported this statement as well as the group between 51 and 68. In 2014, the age group 46-50 consumed 142.43 L/cap/d, and the age group 51-68, 144.64 L/cap/d. Furthermore, it can be summarised that in the metropolitan region Helsinki the water consumption was increasing when the average household age was increasing.

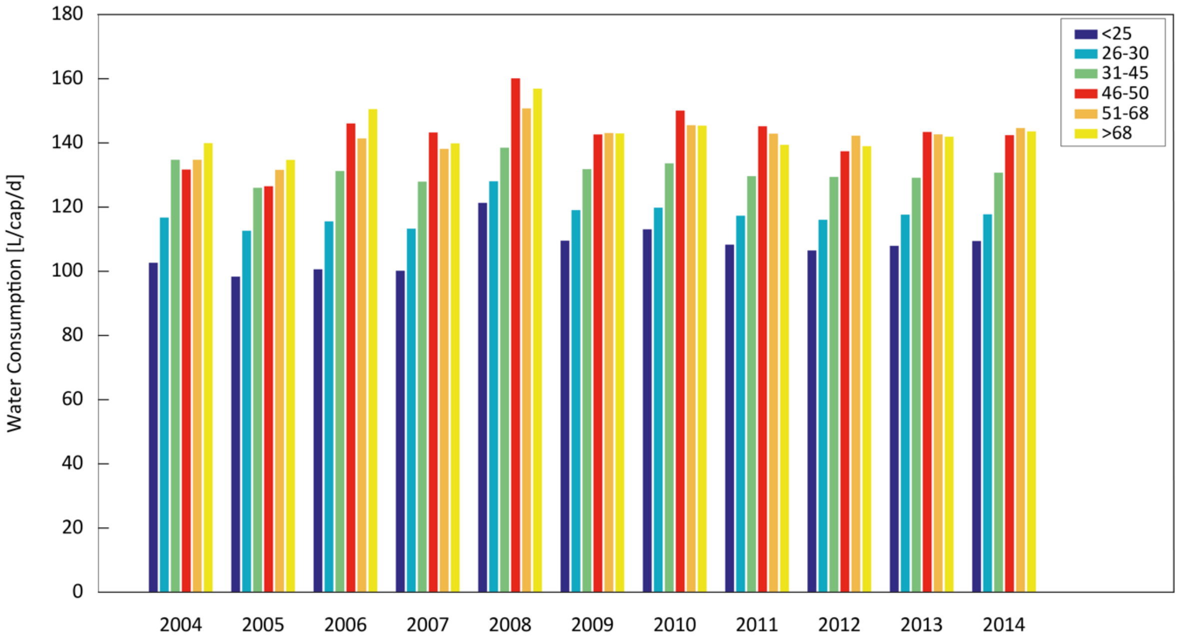

Figure 7: The development of the residential per person consumption (L/cap/d) depending on the average age of the household in Helsinki during the period 2004-2014. The dark blue bars represent the consumption for the group with an average household age ≤25, the petrol bars for group 26-30, the green bars for the group 31-45, the red bars for the group 46-50, the orange bars for the group 51-68, and the yellow bars for the group with an average household age ≥68.

The historical trend evaluation showed quite varying results. Most of the groups had a small positive or negative linear trend in consumption. The age groups ≤25, 26-30, 46-50, and 51-68 had an increasing linear trend, the age group 31-45 had a decreasing linear trend, and the age group ≥68 had no linear trend. A strong correlation existed for the group 51-68 with a p-value of 0.06105, and a R^2 of 0.33718, and a low correlation for the group ≥68 with a p-value of 0.99689, and a R^2 of 0. The second-best fit was achieved for the group ≤25 with a p-value of 0.16918, and a R^2 of 0.19889. The fit of the other groups was varying. All the results can be found in table A 7 in appendix 7.

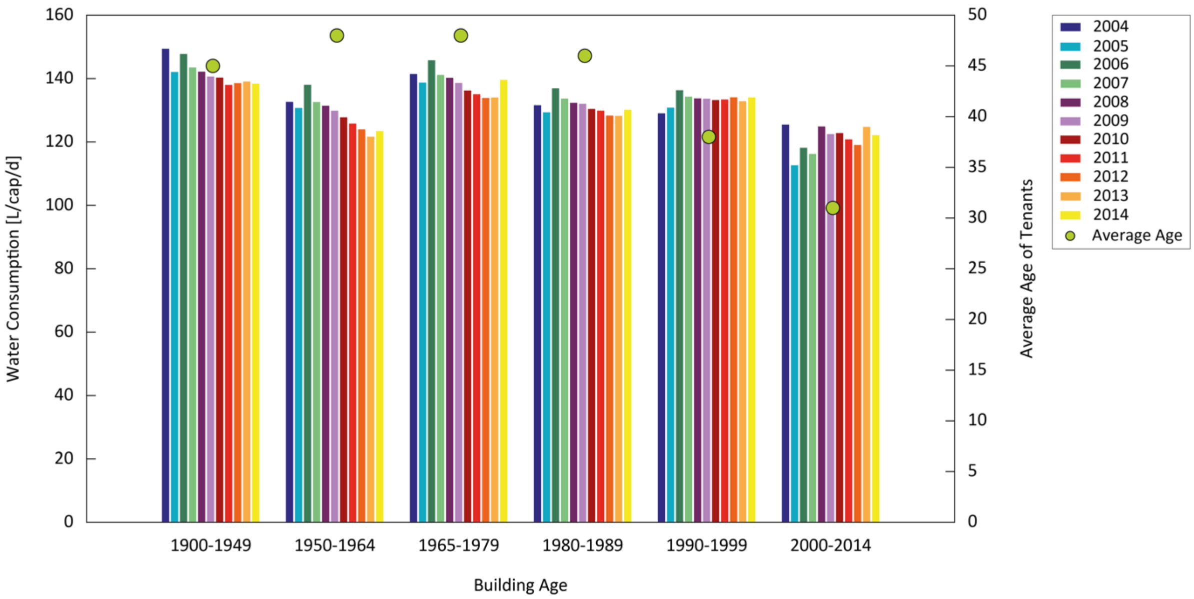

Figure 8: The connection between the age of the building and the average age of the household. The average per person consumption during the period 2004-2014 presented for the six defined building age groups. The first group includes buildings constructed between 1900 and 1949, the second group between 1950 and 1964, the third group between 1965 and 1979, the fourth group between 1980 and 1989, the fifth group between 1990 and 1999, and the sixth group includes buildings constructed between 2000 and 2014. The average age of each group is presented with the light yellow-green dot. Moreover, for all of the building age groups, consumption in 2004 is presented with the dark blue bars, in 2005 with light blue bars, in 2006 with dark green bars, in 2007 with light green bars, in 2008 with dark purple bars, in 2009 with light purple bars, in 2010 with dark red bars, in 2011 with light red bars, in 2012 with dark orange bars, in 2013 with light orange bars, and in 2014 with yellow bars.

To support this result, the building age was observed in combination with the age of the tenants. The aim was to find out if younger people saved really more water or if this is influenced by something else, e.g. the construction year of the building. The results of the analysis of connection between the water consumption depending on the age, and the age of the building is presented in figure 8. The average age of the tenants in buildings built between 2000 and 2014 was 31, while in buildings built between 1950 and 1979 the average age was 48. Moreover, the average age of the tenants in houses built between 1900 and 1989 was over 40, and in the new houses over 30.

4.1.3 Water Demand – Household Size

The results for the historical evaluation of the water consumption influenced by the household size corresponded to the results from the literature (see section 2.1.1.1). The results are presented in figure 9. Single households (dark blue) consumed more water than big families or households (yellow). In 2014, the average daily consumption of a single household in the metropolitan region Helsinki was 193.68 L/cap/d, which was 67.18% more than the average consumption. Compared to that a household with 3-4 persons (green) consumed just 123.22 L/cap/d, and households with 11-14 inhabitants (yellow) just 117.35 L/cap/d in 2014. However, households with a size of 5-6 people (red) consumed 115.53 L/cap/d. It was the lowest of all groups, and was equal to the average residential consumption in 2014.

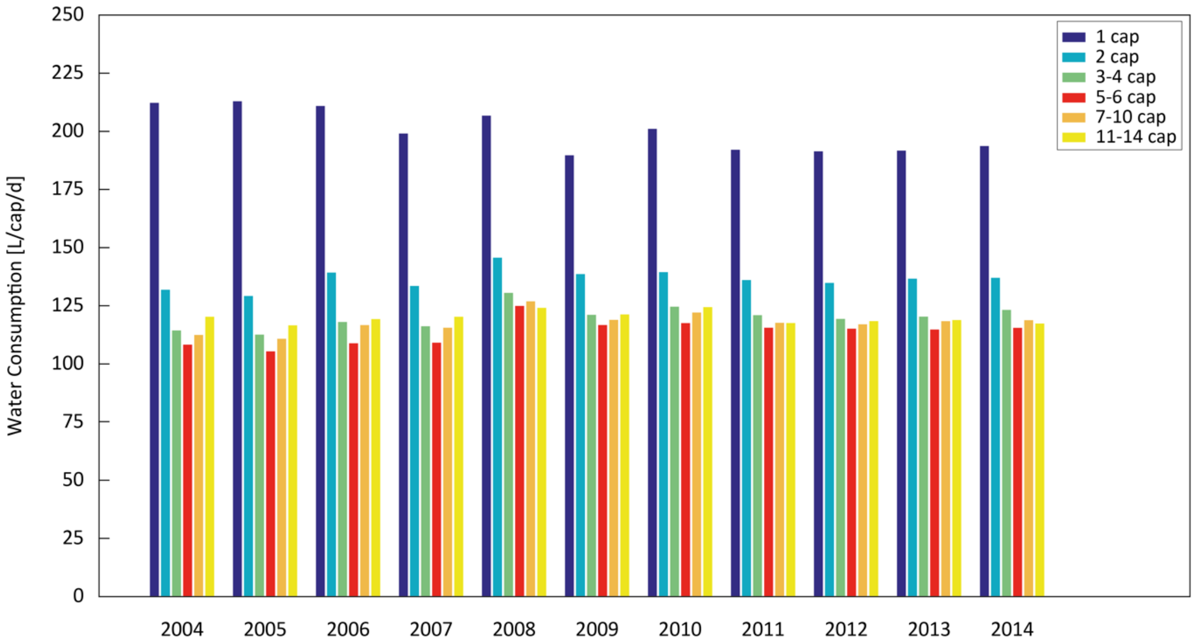

Figure 9: The development of the residential per person consumption (L/cap/d) depending on the household size in Helsinki during the period 2004-2014. The consumption of single households is presented with dark blue bars, two-person households with petrol bars, 3-4 people households with green bars, 5-6 people households with red bars, 7-10 people households with orange bars, and 11-14 people households with yellow bars.

The increase of people within a household leads to the result that the needed amount of water for various water uses increases proportionally less than the number of people living within a household (Schleich & Hillenbrand 2009). The example of the consumption values (2014) in case of a proportional growth (orange solid line) and according to the calculated analysis results (blue solid line) in figure 10 confirmed the statement of Schleich & Hillenbrand (2009).

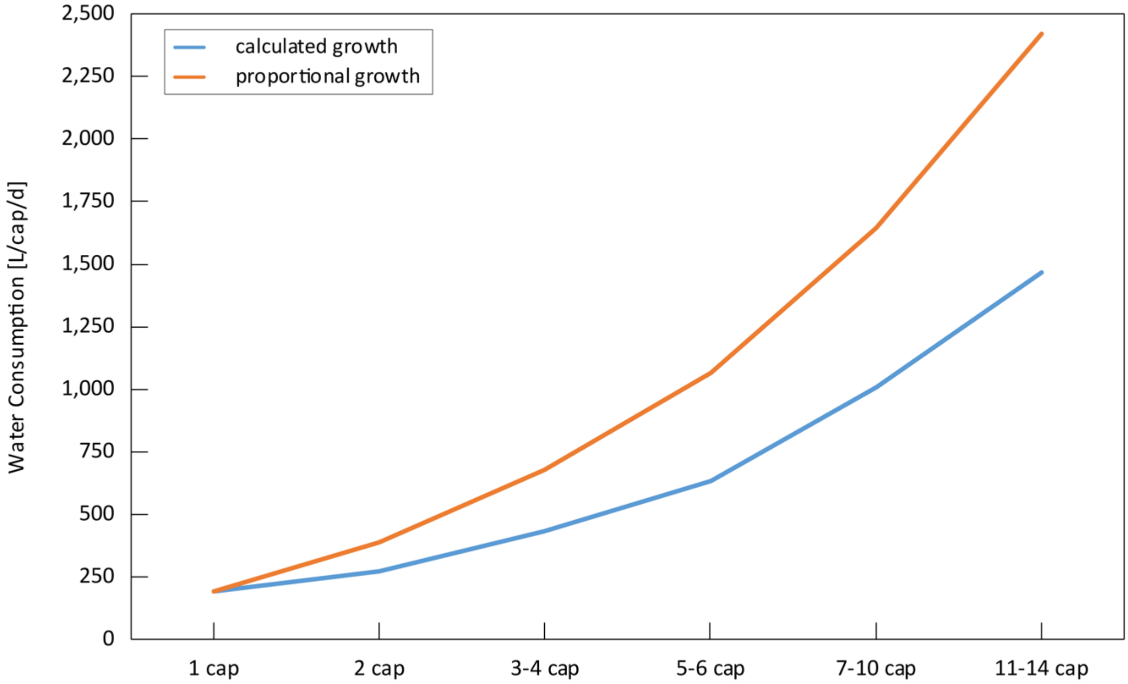

Figure 10: Comparison of the development of water consumption in case of a proportional growth and according to the calculated analysis results. The red line presents how the consumption in 2014 develops, if the increase in household size results in a proportional growth of the consumption. The blue line presents how the calculated consumption in 2014 increases with the population size.

A look at the historical trend evaluation showed good results for this analysis, as all groups had a positive or negative linear trend. Big households had a slight linear trend compared to the other groups. A closer look on the results showed that the groups of 2, 3-4, 5-6, and 7-10 person households had an increasing linear trend, while 1 and 11-14 person households had a decreasing linear trend. A strong correlation existed for the group of single households with a p-value of 0.00109, and a R^2 of 0.71241. The group with 11 or more people had a p-value of 0.64834, and an R^2 of 0.02413, so correlation was low. All other results are listed in table A 7 in appendix 7.

4.1.4 Water Demand – Building Age

Figure 11 shows that the new buildings (yellow) consumed 122.16 L/cap/d of water, which was less than the others in 2014. This group was followed by the residential buildings built between 1950 and 1964 (petrol) with a consumption of 123.43 L/cap/d. The highest consumer group were the buildings built between 1965 and 1979 (green) with a consumption of 139.60 L/cap/d in 2014. During the observation period the trend was a reduction in consumption in the buildings constructed between 1900 and 1989, while the consumption in the buildings constructed between 1990 and 2014 tend to increase.

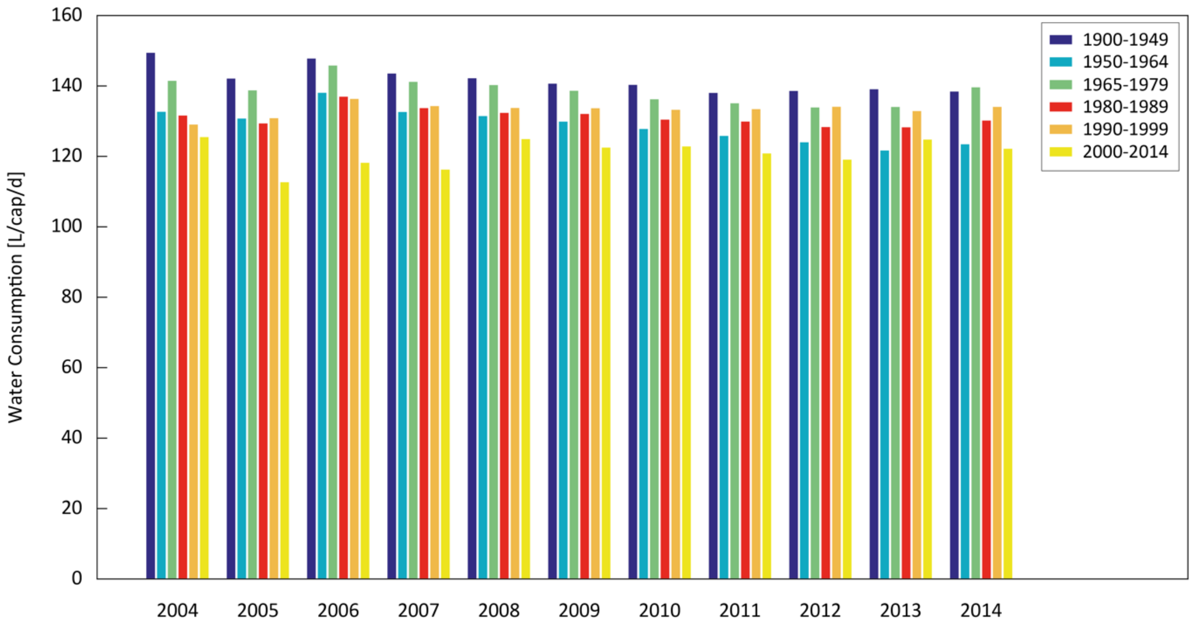

Figure 11: Residential per person consumption (L/cap/d) depending on the year of construction of the building in Helsinki during the period 2004-2014. The consumption of the buildings constructed between 1900 and 1949 is presented with dark blue bars, between 1950 and 1964 with petrol bars, between 1965 and 1979 with green bars, between 1980 and 1989 with red bars, between 1990 and 1999 with orange bars, and the buildings constructed between 2000 and 2014 with yellow bars.

This trend was also seen through the results of the historical trend evaluation. A decreasing linear trend was seen for all buildings constructed between 1900 and 1989, while the groups from 1990 to 2014 had an increasing linear trend. The best fit was found for the building age group 1950 till 1964 with a p-value of 0.00043, and a R^2 of 0.76398. After the construction year 1989, the good fit of the historical trend evaluation decreased. For the group of buildings constructed from 2000 until 2014 the least fitting values were found with a p-value of 0.34725, and a R^2 of 0.09851. In the overall the results of this factor had the best fit compared to the results of the other groups (see appendix 7, table A 7). Therefore, the analysis of the building age was the one with most reliable results.

4.1.5 Water Demand – Water Meter

Based on the small number of input data points (Table 7) this analysis had probably the highest uncertainties. This applied especially for the results of the buildings constructed after 2011. Additional to that the assumption, that all buildings after 2011 had installed and used individual meter, can falsify the results.

Table 7: Overview data input points water meter analysis

Year	19080-1989	1990-1999	2000-2010	After 2011
2011	10345	7519	8379	257
2012	10357	7517	7985	806
2013	10320	7522	8000	1134
2014	10318	7528	8021	1812

The strong variation of the results in the group of buildings built in 2011 and onwards (green) was also visible in the figure 12. The lowest consumption was calculated for the group built in 2000-2010 (yellow), followed by the group built in 1980-1989 (red), and the highest consumption for the group built in 1990-1999 (orange). However, the consumption in the buildings with the construction year between 2000 and 2010 was slowly increasing from 121.51 L/cap/d in 2011 to 125.20 L/cap/d in 2014.

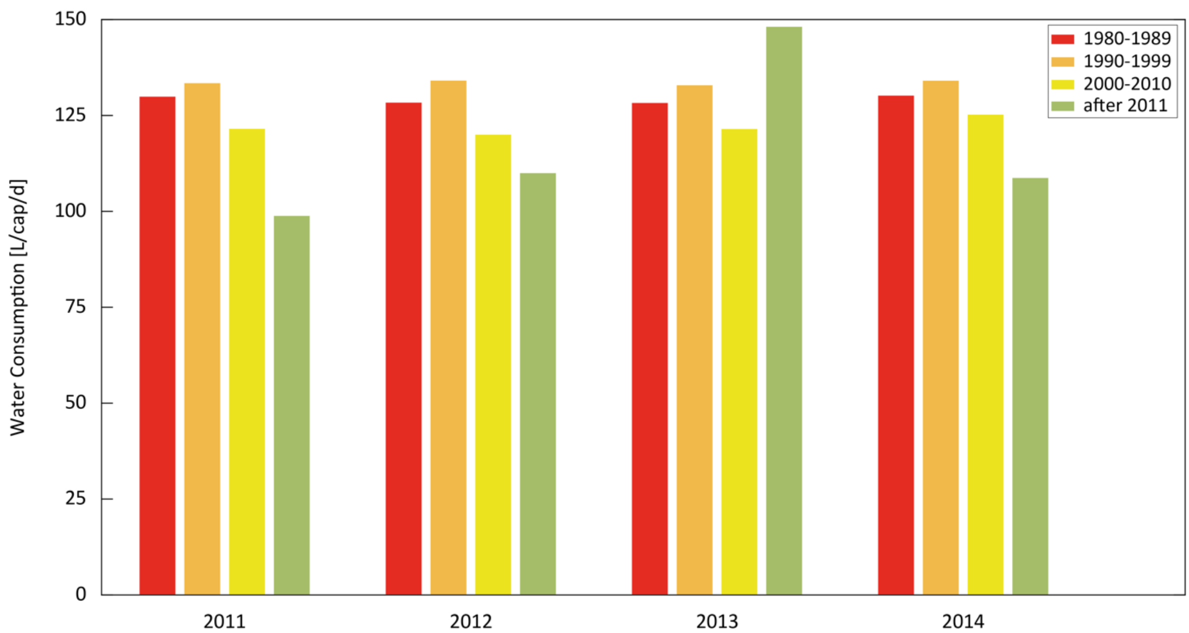

Figure 12: Residential per person consumption (L/cap/d) depending on the use of a common water meter (all categories before 2011) or an individual meter (categories after 2011) in Helsinki for the years 2011 to 2014. The buildings are divided into groups based on their construction year. Buildings built between 1980 and 1989 are presented with red bars, between 1990 and 1999 with orange bars, between 2000 and 2010 with yellow bars, and buildings built after 2011 with green bars.

In the two groups of buildings built between 1980-1999 was no linear trend existent, while in the two groups of buildings built between 2000-2014 a small increasing linear trend existed. The best fit was found for the group with the construction year in the 80s', with a p-value of 0.89834, and a R^2 of 0.01033. The buildings constructed between 2000 and 2010 had the lowest correlation with a p-value of 0.27121, and an R^2 of 0.53113. The other results are listed in in table A 7 in appendix 7.

Another way to define the effect of the installation of individual water meters in the metropolitan region Helsinki was based on four buildings where the individual water meters were already installed according to Oikotie webpage (Table 8) (Oikotie n.d.).

Table 8: Overview of the results from the consumption analysis of the individual meters installed in blocks (Oikotie n.d.)

City		**Espoo**		**Helsinki**	**Vantaa**
Building code		A	B	C	D
Building year		2012	2011	1960	1968
Year of plumbing renovation				2013	2012
Building purpose		Kerrostalo	Kerrostalo	Kerrostalo	Kerrostalo
Average number of inhabitants	2010			265	237
	2011		75	263	234
	2012	119	205	249	246
	2013	125	173	245	246
	2014	132	307	277	249
Water consumption [L/cap/d]	2010			91.93	103.78
	2011		147,74	91.87	115.61
	2012	97.97	132,98	81.82	101.54
	2013	122.91	213,18	62.27	94.62
	2014	112.43	123,72	54.90	93.72

However, it cannot be said if the meters were really used or not. The results in table 8 and figure 13 show at least for the new buildings (B (blue), A (green)) no concrete or reliable results. Moreover, a clear trend in reduction was visible for the renovated buildings (C (red), D (orange)), even if the number of inhabitants in the block D (orange) had not changed anymore after 2012 and in block C (red) the number of inhabitants increased in 2014. The best conversion effects after renovation were seen at block C, where the consumption decreased from 91.93 L/cap/d in 2010 to 54.90 L/cap/d in 2014.

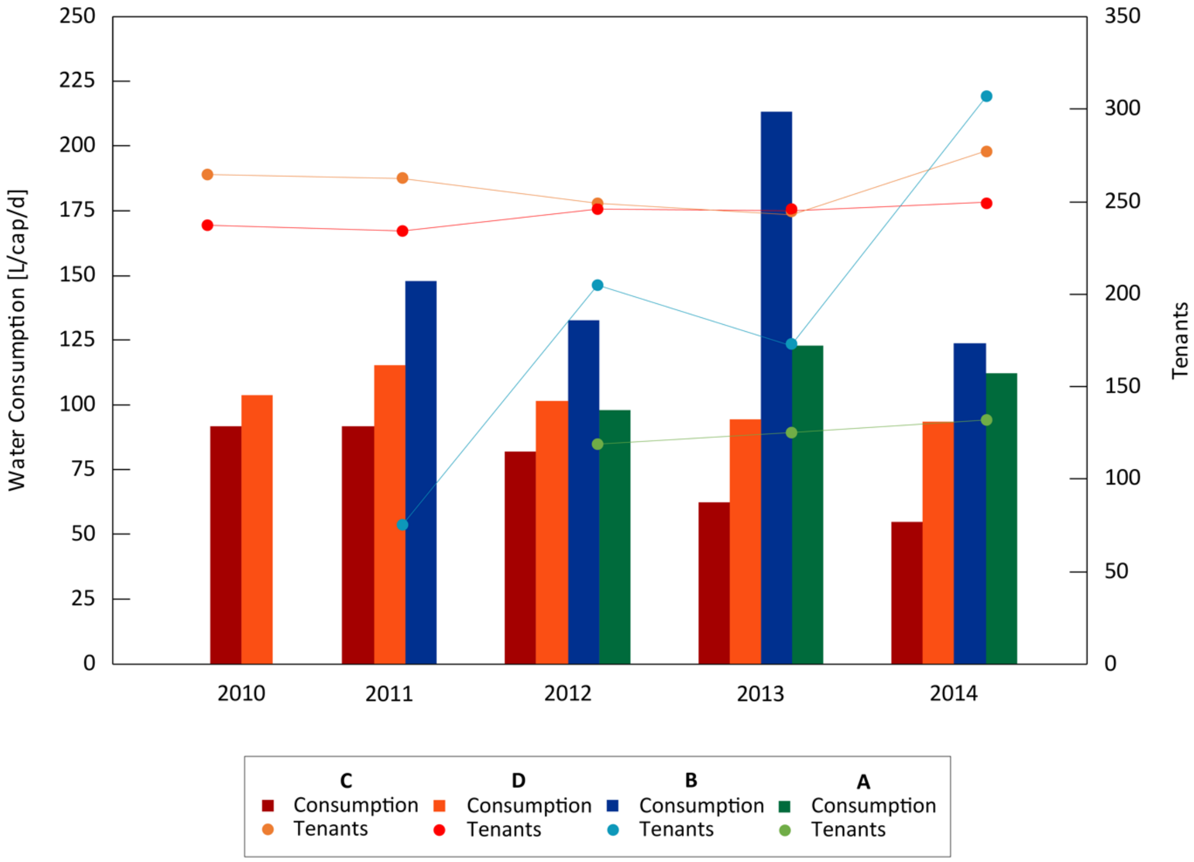

Figure 13: Implementation of the additional information of the influence on the water consumption (L/cap/d) after installing an individual meter for two renovated buildings (C and D) as well as for two new buildings (A and B) plus the according development of the tenants for the time frame 2010 until 2014. The consumption of C is presented with the dark red bars and the number of tenants with red dots connected with lines. The consumption of D is presented with dark orange bars and the number of tenants with orange dots connected with lines. The consumption of B is presented with dark blue bars and the number of tenants with light blue dots connected with lines. The consumption of A is presented with dark green bars and the number of tenants with light green dots connected with lines.

4.1.6 Water Demand – Income

The aim behind this analysis was also to see the influence of the law change from 2011. The main outcome from the influence on the income was, that no connections were seen between those two factors. The results were different from the results of the other studies. Starting with the analysis on district level (Figure 14), the consumption was highest in the Eteläinen suurpiiri (Figure A 1) with an average income of 46,098 €/cap/a, and the lowest in the Itäinen suurpiiri (Figure A 1) with an average income of 27,269 €/cap/a in 2014. However, the highest consumption was found in the Keskinen suurpiiri (Figure A 1), with an average consumption of 209.02 L/cap/d, and the lowest in the Pohjoinen suurpiiri (Figure A 2), with an average consumption of 153.13 L/cap/d in 2014. So, the theoretical and analysed results did not correspond with each other. For three districts, which are Läntinen, Pohjoinen, and Kaakkoinen suurpiiri (Figure A 2), a small connection between income and consumption was seen in 2011.

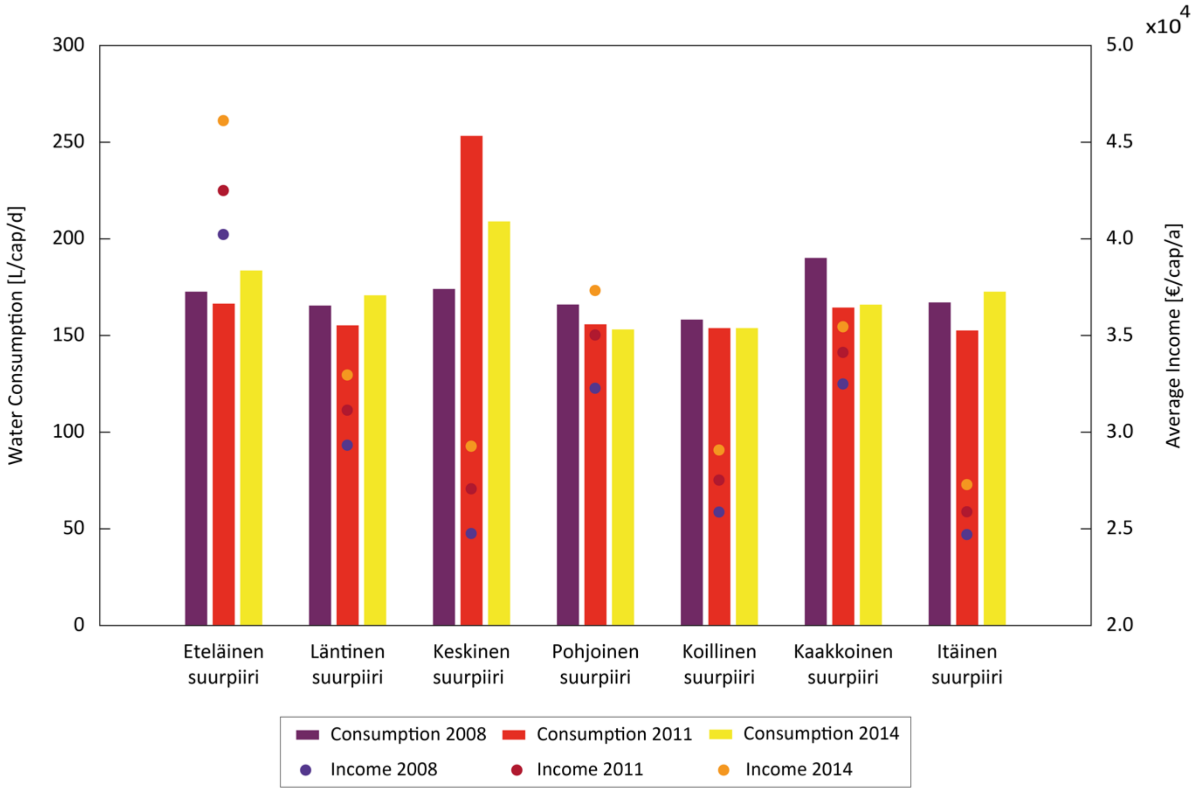

Figure 14: The dependence of water consumption (L/cap/d) and the average income (€/cap/a) for the major districts (suurpiiri) in Helsinki for the years 2008, 2011, and 2014. The consumption in 2008 is presented with dark purple bars, in 2011 with red bars, and in 2014 with yellow bars. The average income in 2008 is presented with purple dots, in 2011 with dark red dots, and in 2014 with orange dots.

Moreover, 2011 was also the year where a small increase in the linear trend was visible. This was also underlined by the good fit of the p-value, of 0.60127, and the R^2 of 0.05851. The strongest correlation with a p-value of 0.95634, and an R^2 of 0.00066, was calculated for the year 2014, even if there was no linear trend present. The lowest correlation was calculated for year 2008 with an p-value of 0.45977, and a R^2 of 0.11359.

From the analysis using income groups (Figure 15), it was seen that the consumption increased slightly if the income increased, especially in 2014 (yellow). From that general overview of the results, the two outstanding bars were excluded. The income group 22,500 till 29,999 €/cap/a seemed to be an outlier. In 2011 (red) the consumption was 238.34 L/cap/d, which was much higher compared to the consumption of 174.13 L/cap/d in 2008, and 163.14 L/cap/d in 2014. The other outlier was in the income group 45,000 till 54,999 €/cap/d with a consumption of 217.32 L/cap/d in 2008 (dark purple). This was also much higher than the consumption of 149.16 L/cap/d in 2011, and 155.13 L/cap/d in 2014. Therefore, it seemed that those two results are not reliable, as this high variety in consumption was unrealistic. Another trend, which was seen was that the consumption slightly decreased between the income groups 22,500-29,999 €/cap/a, and 45,000-54,999 €/cap/a in nearly each of the observed years.

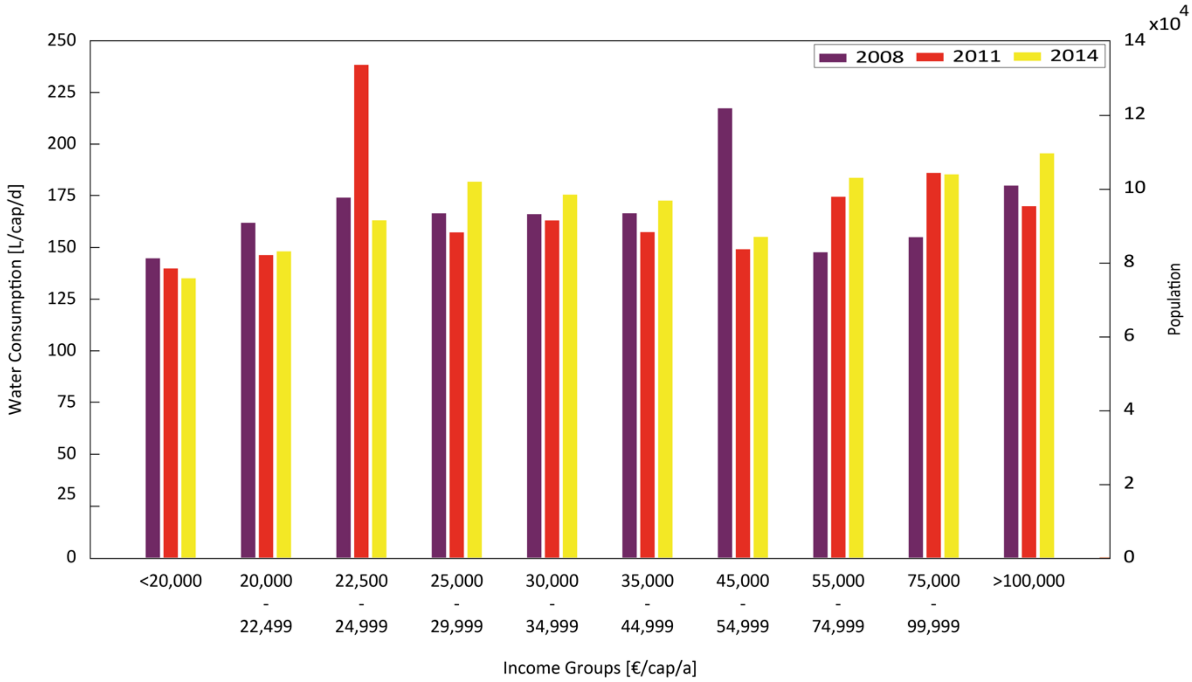

Figure 15: The dependence of water consumption (L/cap/d) and annual income of selected income groups (€/cap/a) in Helsinki for the years 2008, 2011 and 2014. Based on the annual income, people are divided into eight income groups and presented on x-axis. These groups are ≤ 20.000 €/cap/a, 20.000-22.499 €/cap/a, 22.500-25.999 €/cap/a, 25.000-29.999 €/cap/a, 30.000-34.999 €/cap/a, 35.000-44.999 €/cap/a, 45.000-54.999 €/cap/a, 55.000-74.999 €/cap/a, 75.000-99.999 €/cap/a, and ≥ 100.000 €/cap/a. The consumption in 2008 is presented with dark purple bars, in 2011 with red bars, and in 2014 with yellow bars.

The analysed results were also verified through the linear trend. The highest increasing linear trend was seen for 2014, which had also the strongest correlation with a p-value of 0.01792, and a R^2 of 0.52413. This was followed by year 2011 with a slight increasing linear trend as well as a p-value of 0.70152, and an R^2 of 0.01935. Year 2008 had the least linear trend and also low correlation with a p-value of 0.82425, and an R^2 of 0.00654.

4.2 Forecast

The analysis results for forecasts for the metropolitan region, and on district level, are shown in the following subsections. The forecasts on city level for Helsinki, Espoo, and Vantaa can be seen in the appendix 6.

4.2.1 Metropolitan Region Helsinki

The main result for the forecast was, that the consumption per person and day is slightly decreasing, and the total residential consumption is increasing. The amount of the consumption differed between the forecast versions. The results are presented in the following sections.

4.2.1.1 First Version

The results for this forecast version of the water consumption of the metropolitan region are displayed until 2040 in figure 16. The population increased from 1,098,728 inhabitants in 2015 to 1,368,271 inhabitants in 2040. Moreover, the total residential consumption increased from 46.21 M m^3/a in 2015 up to 47.87 M m^3/a in 2040, while the per person consumption per day decreased from 115.23 L/cap/d in 2015 to 95.85 L/cap/d in 2040.

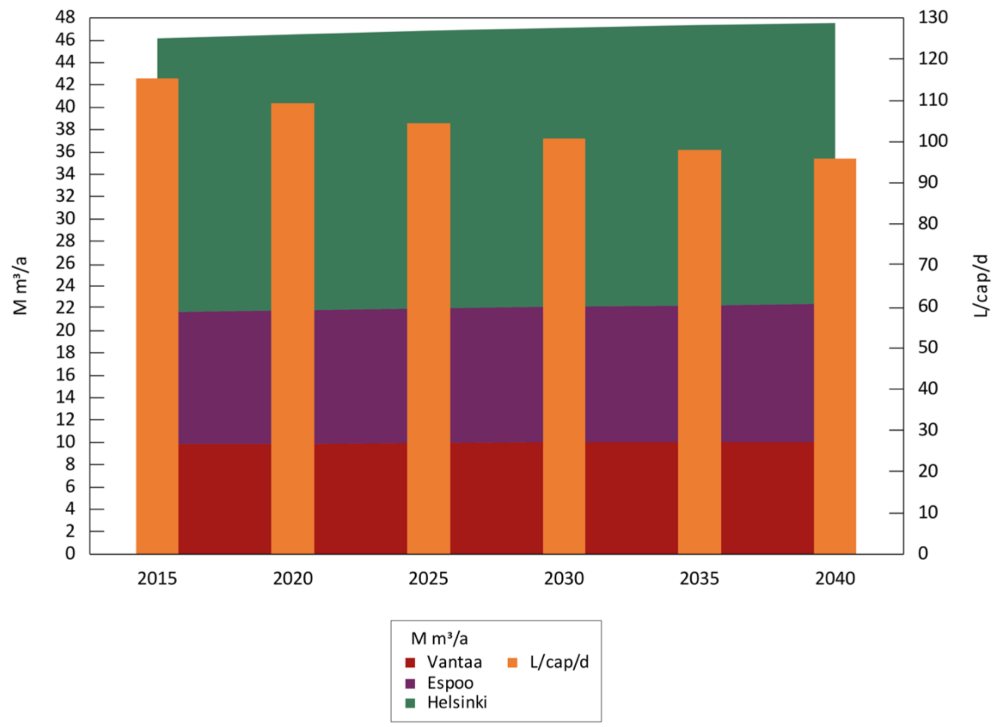

Figure 16: The first forecast version of the total water consumption (M m^3/a) and the average consumption (L/cap/d) for the metropolitan region Helsinki until 2040. The total consumption on the left y-axes is presented as a plane diagram, where the region is divided into the cities of Helsinki (green), Espoo (purple), and Vantaa (red). The future per person consumption on the right y-axes is presented with orange bars in 5-year-steps.

4.2.1.2 Second Version

The results for the second forecast version of the water consumption of the metropolitan region until 2040 are shown in figure 17. The difference compared to the first forecast version was that the total residential consumption just slightly increased, from 44.90 M m^3/a in 2015 to 45.16 M m^3/a in 2020. Following the consumption will decrease to 44.95 M m^3/a in 2040, even if the population will continuously increase (see appendix 5, table A 5). As already mentioned in the introduction of this section, the per person consumption per day was also in this forecast version decreasing from 111.95 L/cap/d in 2015 to 90.00 L/cap/d in 2040.

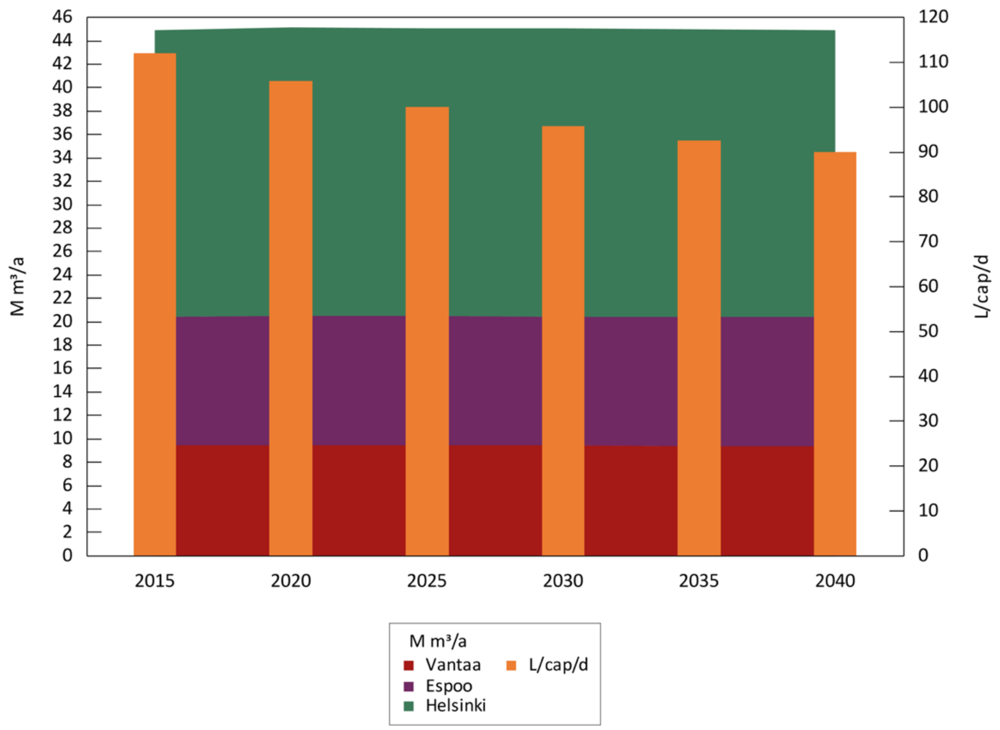

Figure 17: The second forecast version of the total water consumption (M m^3/a) and the average consumption (L/cap/d) for the metropolitan region Helsinki until 2040. The total consumption on the left y-axes is presented as a plane diagram, where the region is divided into the cities of Helsinki (green), Espoo (purple), and Vantaa (red). The future per person consumption on the right y-axes is presented with orange bars in 5-year-steps.

4.2.2 City Districts of Helsinki (suurpiiri)

For the seven observed city districts in Helsinki, the trend of an increasing total residential consumption, and a trend of decreasing per person consumption was seen. The results are presented in the following subsections. Some districts showed a stronger trend, while small trends occurred in the other districts. The amount of increase or decrease in consumption depended on the used forecast version as before. The forecast was created until 2025.

4.2.2.1 First Version

The development of the total amount of the residential consumption until 2025 is observed and presented in figure 18. At the Keskinen suurpiiri, the consumption slightly increased from 2.04 M m^3/a in 2015 up to 2.06 M m^3/a in 2017. This increase was followed by a decrease down to 2.00 M m^3/a in 2021, and after that an increase up to 2.08 M m^3/a in 2025.

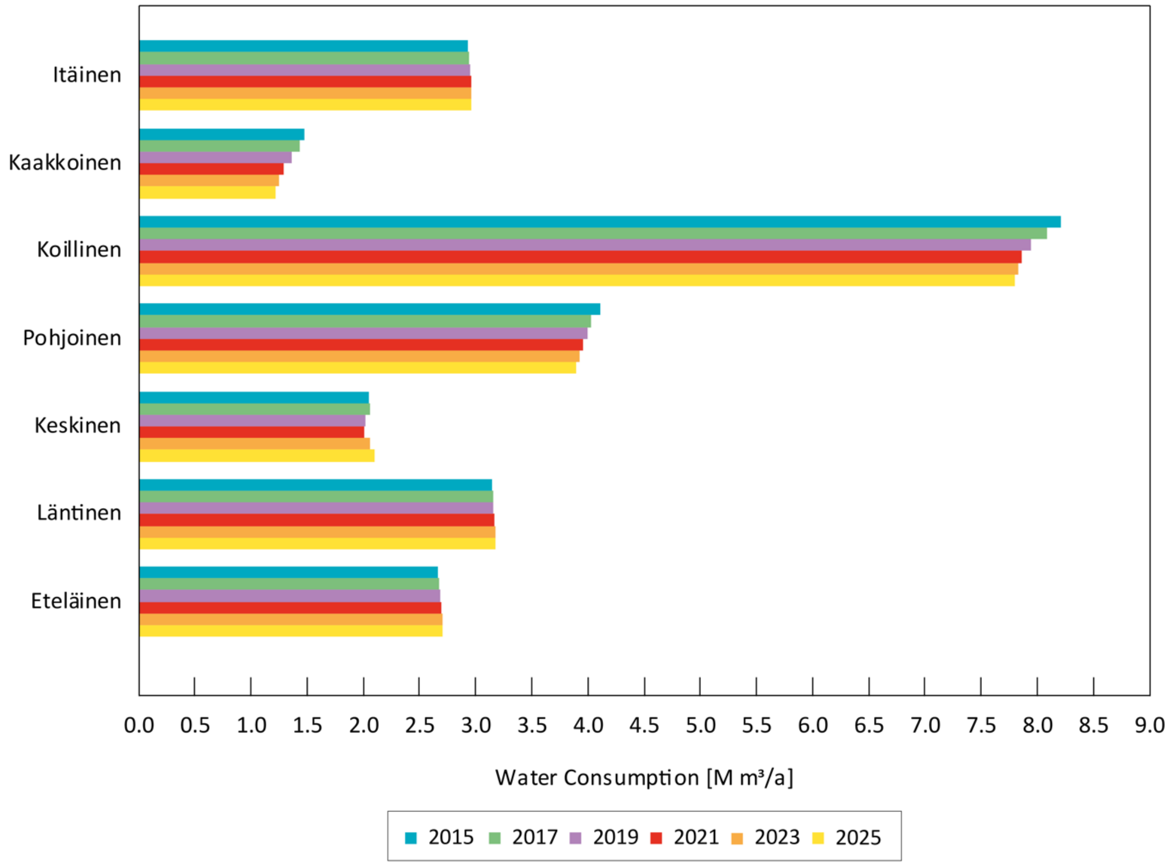

Figure 18: The first forecast version of the total water consumption (M m^3/a) for the seven city districts (suurpiiri) of Helsinki from 2015 until 2025. The consumption in 2015 is presented petrol bars, in 2017 with green bars, in 2019 with purple bars, in 2021 with red bars, in 2023 with orange bars, and in 2025 with yellow bars.

The amount of consumed water in the rest of the districts decreased, and results are presented in table 9.

Table 9: Version 1: Change of the total residential consumption between 2015 and 2025 in the city districts

Year	Eteläinen	Läntinen	Keskinen	Pohjoinen	Koillinen	Kaakkoinen	Itäinen
	M m3/a	M m3/a	M m3/a	M m3/a	M m3/a	M m3/a	M m3/a
2015	2.6499	3.1331	2.0379	4.0909	8.1943	1.4660	2.9164
2025	2.6975	3.1671	2.0842	3.8830	7.7812	1.2042	2.9498

A view on the per person consumption in the districts (Figure 19) showed that the consumption decreased. The decrease was variating between 6-11% at most of the districts. Just at the Kakkoinen suurpiiri the per person consumption decreased, about 35%.

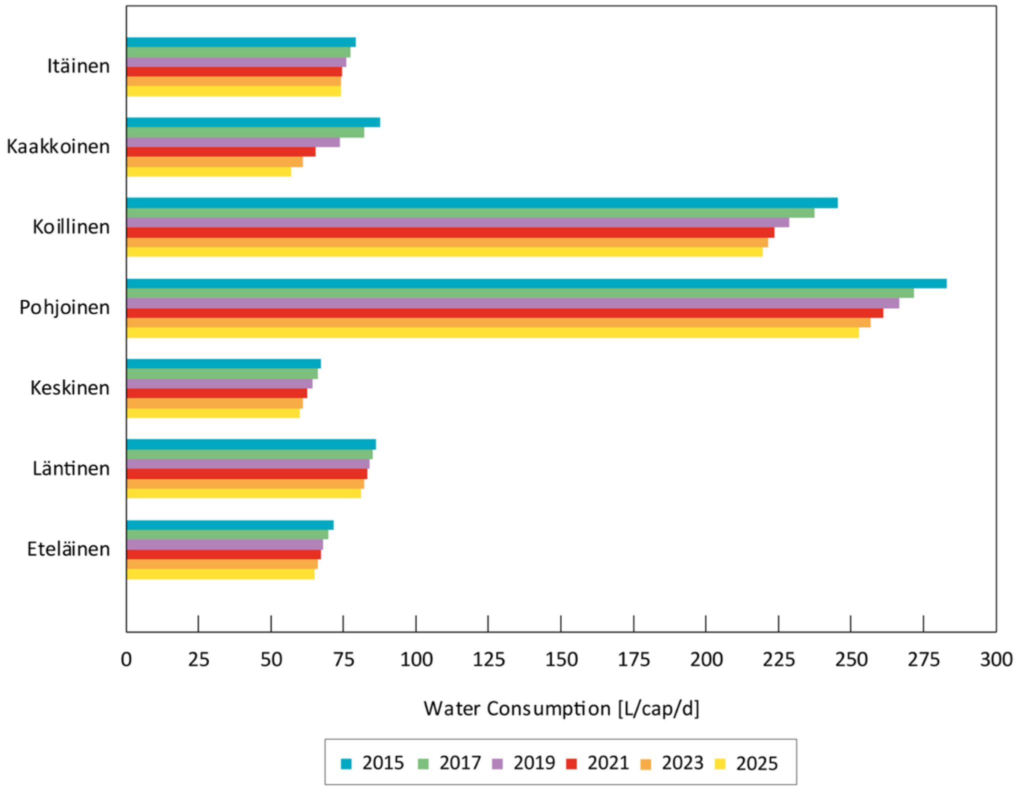

Figure 19: The first forecast version of the consumption per person (L/cap/d) for the seven city districts (suurpiiri) of Helsinki from 2015 until 2025. The consumption in 2015 is presented petrol bars, in 2017 with green bars, in 2019 with purple bars, in 2021 with red bars, in 2023 with orange bars, and in 2025 with yellow bars.

The most significant decrease between 2015 and 2025, occurred in the districts Pohjoinen, Koillinen, and Kaakkoinen and was around 30 L/cap/d. As an example, the per person consumption in the Pohjoinen suurpiiri was 265.48 L/cap/d in 2015, and decreased to 237.01 L/cap/d in 2025. The lowest decrease occurred in the Itäinen suurpiiri, where the consumption decreased from 74.01 L/cap/d in 2015 to 69.43 L/cap/d in 2025. The results for the other districts can be seen at table 10.

Table 10: Version 1: Change of the residential per person consumption between 2015 and 2025 in the city districts

Year	Eteläinen	Läntinen	Keskinen	Pohjoinen	Koillinen	Kaakkoinen	Itäinen
	L/cap/d	L/cap/d	L/cap/d	L/cap/d	L/cap/d	L/cap/d	L/cap/d
2015	67.0929	80.7615	62.9820	265.4795	230.1568	82.0153	74.0116
2025	60.8536	76.0084	56.0459	237.0073	205.7029	53.3176	69.4323

4.2.2.2 Second Version

Also in the second forecast version, the change in consumption in the Keskinen suurpiiri behaved differently than in other districts. The consumption slightly increased from 2.03 M m^3/a in 2015 up to 2.06 M m^3/a in 2016. This increase was followed by a decrease down to 2.03 M m^3/a in 2020, and after that increase up to 2.07 M m^3/a in 2025. All the results for this forecast are displayed in figure 20.

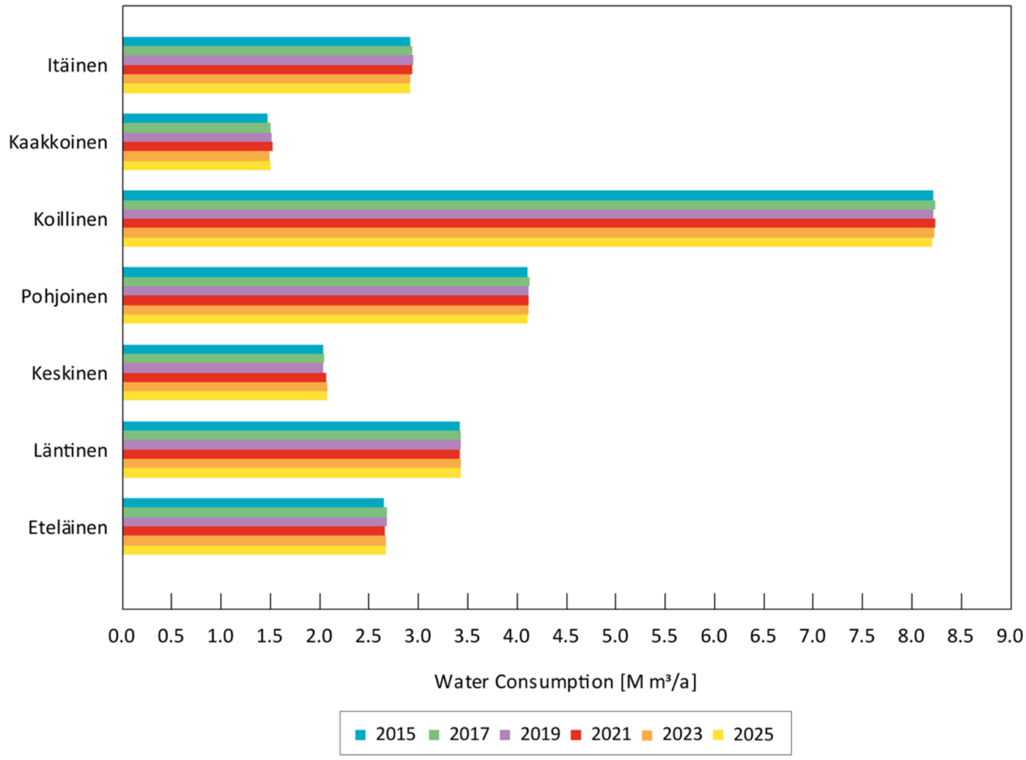

Figure 20: The second forecast version of the total water consumption (M m^3/a) for the seven city districts (suurpiiri) of Helsinki from 2015 until 2025. The consumption in 2015 is presented petrol bars, in 2017 with green bars, in 2019 with purple bars, in 2021 with red bars, in 2023 with orange bars, and in 2025 with yellow bars.

In all other six districts the total consumption slightly increased (Table 11).

Table 11: Version 2: Change of the total residential consumption between 2015 and 2025 in the city districts

Year	Eteläinen	Läntinen	Keskinen	Pohjoinen	Koillinen	Kaakkoinen	Itäinen
	M m3/a	M m3/a	M m3/a	M m3/a	M m3/a	M m3/a	M m3/a
2015	2.6465	3.4088	2.0328	4.0990	8.2104	1.4689	2.9126
2025	2.6679	3.4192	2.0652	4.0968	8.1990	1.4980	2.9074

On the other hand, the per person consumption decreased ongoing, according to the forecast until 2025 (Figure 21). This was the same in each district, just the amount differed between the districts.

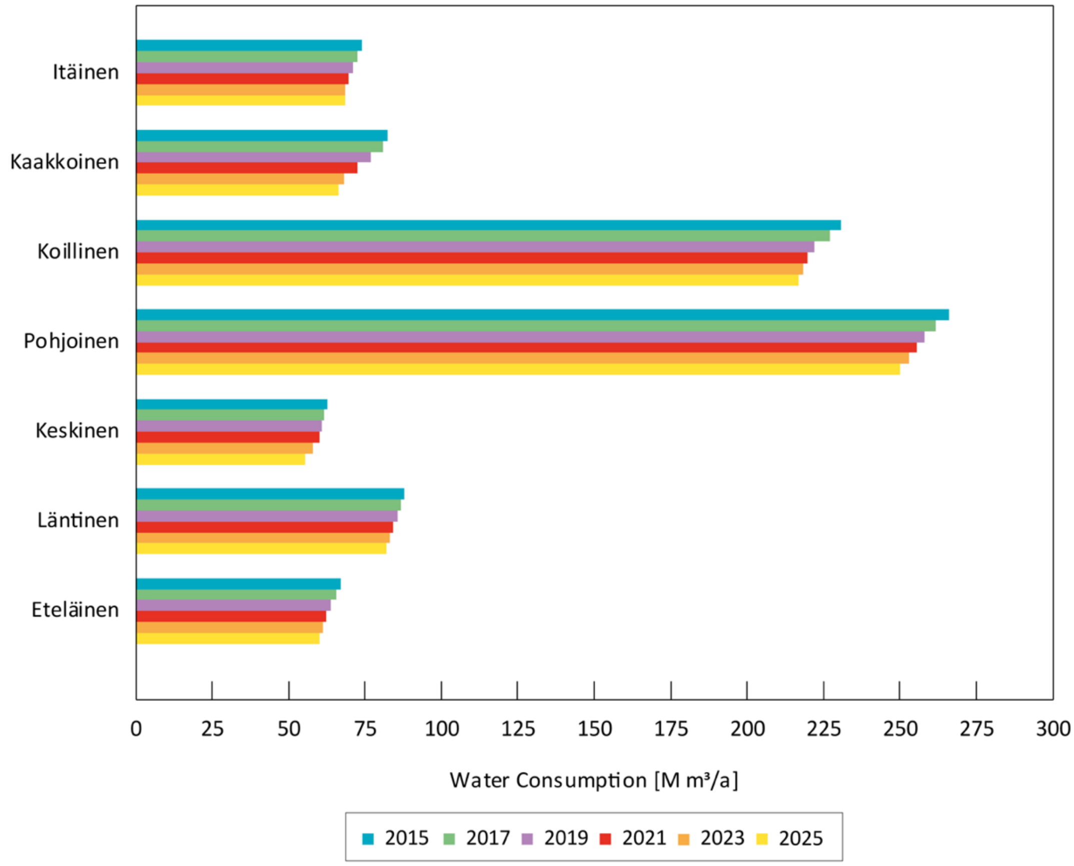

Figure 21: The second forecast version of the consumption per person (L/cap/d) for the seven city districts (suurpiiri) of Helsinki from 2015 until 2025. The consumption in 2015 is presented petrol bars, in 2017 with green bars, in 2019 with purple bars, in 2021 with red bars, in 2023 with orange bars, and in 2025 with yellow bars.

In the second forecast version, the most significant decrease between 2015 and 2025 occurred in the districts Koillinen and Kaakkoinen. The per person consumption in the Koillinen suurpiiri was 230.61 L/cap/d in 2015, and decreased to 216.75 L/cap/d in 2025. In the Kaakkoinen suurpiiri the per person consumption decreased from 82.18 L/cap/d in 2015 to 66.32 L/cap/d in 2025. The lowest decrease occurred in the districts Itäinen and Läntinen. In the Itäinen suurpiiri the consumption decreased from 73.92 L/cap/d in 2015 to 68.43 L/cap/d in 2025. The per person consumption in the Läntinen suurpiiri decreased from 87.87 L/cap/d in 2015 to 82.06 L/cap/d in 2025. The results for all districts can be seen at table 12.

Table 12: Version 2: Change of the residential per person consumption between 2015 and 2025 in the city districts

Year	Eteläinen	Läntinen	Keskinen	Pohjoinen	Koillinen	Kaakkoinen	Itäinen
	L/cap/a	L/cap/a	L/cap/a	L/cap/a	L/cap/a	L/cap/a	L/cap/a
2015	67.0058	87.8674	62.8219	266.0017	230.6095	82.1766	73.9154
2025	60.1870	82.0562	55.5339	250.0562	216.7483	66.3250	68.4354

4.2.3 Capacity of the HSY Waterworks

To check if the current, and planned maximum capacity of the HSY waterworks in Vanhakaupunki, and Pikäkoski were well-designed for the future needs, an approximate calculation with the provided capacities was performed (Table 13). The calculations showed that the capacity can fulfil the current and future needs at the supply area. The maximum consumption during peak periods, and seasonal consumption changes were not considered, which had probably an effect to the results. However, to be able to perform the calculation, the consumption development during the week, the weekends, as well as during the seasons is needed as the current data were the average consumption during a day. Moreover, these calculations included just the cities Helsinki, Espoo, and Vantaa, and were just prepared for the residential consumption. The consumption of Kauniainen will not have a major influence due to the small number of inhabitants, but the other consumption groups (e.g. industry, and public services) will increase the amount of the total consumption. To get an idea, the difference was around 16 M m^3/a, between the residential consumption, and the total consumption in 2014.

Table 13: Approximate calculation if the capacity[7] of the two HSY waterworks will suite the actual (2015) and future need (2040)

<table>
<tr><th colspan="2" rowspan="3">Waterworks HSY</th><th colspan="2" rowspan="2">Capacity</th><th rowspan="2">Total 2015</th><th colspan="2">Need 2015</th><th rowspan="2">Total 2040</th><th colspan="2">Need 2040</th></tr>
<tr><th>Version 1</th><th>Version 2</th><th>Version 1</th><th>Version 2</th></tr>
<tr><th>m^3/h</th><th>m^3/d</th><th>m^3/d</th><th>m^3/d</th><th>m^3/d</th><th>m^3/d</th><th>m^3/d</th><th>m^3/d</th></tr>
<tr><td>Vanhakaupunki</td><td rowspan="2">Actual</td><td>8,000</td><td>192,000</td><td rowspan="3">360,000</td><td rowspan="3">126,603</td><td rowspan="3">123,014</td><td rowspan="3">408,000</td><td rowspan="3">131,151</td><td rowspan="3">123,151</td></tr>
<tr><td rowspan="2">Pitkäkoski</td><td>7,000</td><td>168,000</td></tr>
<tr><td>After 2022</td><td>9,000</td><td>216,000</td></tr>
</table>

[7] The capacity of the waterworks was provided by HSY, based on a request to Veli-Pekka Vuorilehto (Director of Division) via Email on the 13.05.2017.

5 DISCUSSION

This part will focus on the explanation of the meaning of the results of the analysis, and their reliability, as well as discuss about possible uses, and connections to other studies.

5.1 Statistical Evaluation of the Historical Trend

The analysis of the historical trend will indicate necessary focus points for the forecast. Moreover, focus points where the water utilities might need to do some improvements to fulfil their goals or need to step in to promote water conservation. Therefore, it is the most important part of the study. Water conservation is not a major topic or concern in Helsinki, so the results mainly help to understand the current situation, and how the situation will develop in the future in connection with the population forecast. Moreover, the data gaps of the analysis show also possible improvement and expansion possibilities for the data storage of HSY. In the following subsections, the listed topics for the analysed influencing factors are discussed.

5.1.1 Residential Water Consumption

When it comes to the development of the water consumption the total residential water consumption gives an overview of the bigger picture. The reason is that social, environmental, and economic factors (Table 1) affect the residential water consumption (Schleich & Hillenbrand 2009). In Helsinki, the total as well as the per person consumption decreased slowly since 2004. The reason for the reduced per capita consumption can be ascribed to changes to water efficient devices in new constructed or renovated buildings, changes in household technology (e.g. washing machine, dishwasher), an eco-sensitive consumer behaviour, and increasing water prices (Hummel & Lux 2007). This in the end, is influencing the total residential water consumption, and leads to a reduction of the consumption. In Hamburg, the total residential water consumption increased since 2008. According to Kluge et al. (2014) the consumption is increased since 2007. Changes are similar in the per person consumption. The limit of reduction options through renovations or the installation of individual meters are already nearly exhausted (Kluge et al. 2014). The population is continuous rising, and at the same time also the total residential water consumption.

Furthermore, the per person consumption until 2012 was lower in Hamburg than in Helsinki. One possible reason is the different water meter regulations. In Hamburg the installation of individual meters for all existing apartments, and new buildings, as well as the billing of the tenants based on those meters have been required since 2006 (Zenner 2003). In Finland, the mandatory installation of apartment meters in new buildings came into force in 2011, and during corresponding renovation works in 2013 (Finnish Ministry of the Environment 2010). This was much later than in Hamburg. Even though installing individual meters is compulsory, billing based on them is not. Currently tenants of blocks in Finland still pay a certain water-fee per month. Therefore, they probably have no knowledge about their individual water consumption, and so tend to be wasteful with this resource (Agthe & Billings 2002). This might change, if the usage and billing based on individual meters becomes obligatory due to changes in legislation. Another reason is the differences in the water price between the cities. The prices for water in 2017 are 1.40 €/m^3 in Helsinki (HSY 2016), and 1.85 €/m^3 in Hamburg (Water Company of Hamburg 2017). Fixed basic rate is 0.0196 €/floor-m^2/month in Helsinki (HSY 2016), and 2.55 €/month in Hamburg, if there is just one water meter, and an average flow of 1.5 m^3/h (Water Company of Hamburg 2017).[8] A focus on the price for 1 m^3 drinking water shows that water is 0.45 € cheaper in Helsinki compared to Hamburg. The higher water price in Hamburg can lead to a saving behaviour within the population, as higher water prices lead to lower consumption, if water is treated as a pure economic good (Corbella & Pujol 2009).

It is important to mention that the reliability of the calculated results for Hamburg might be low, as the provided data did not include information about the actual residential consumption, and the gathered population data were just for the total area of Hamburg, and not for the whole supply area. To provide a more reliable comparison, also more detailed information for Hamburg will be necessary, e.g. population of the whole supply area, and the actual residential water consumption.

5.1.2 Water Demand – Average Age of the Household

The results of the analysis about the water consumption depending on the household age in Helsinki corresponded to the studies of Schleich & Hillenbrand (2009), and Williamson et al. (2002). In households with a lower average age, the per person consumption was lower compared to households with a higher average age. One reason can be, that working lives become

[8] The listed water prices are already the gross price.

more flexible (Boyer et al. 2012), and therefore younger people spend less time at home compared to older people.

According to the new patterns of everyday live new food habits are shaped (Boyer et al. 2012). For lunch, most of the employees use their cafeterias at work or eat their lunch in restaurants, then they do not prepare anything at home or do not have the time to eat lunch at home (Figure 22). In 2004 54% of men, and 48% of women reported in an employee study for Helsinki, that they prefer lunch at a worksite canteen, whereas 19% of men, and 39% of women prefer a packed lunch (Raulio 2011).

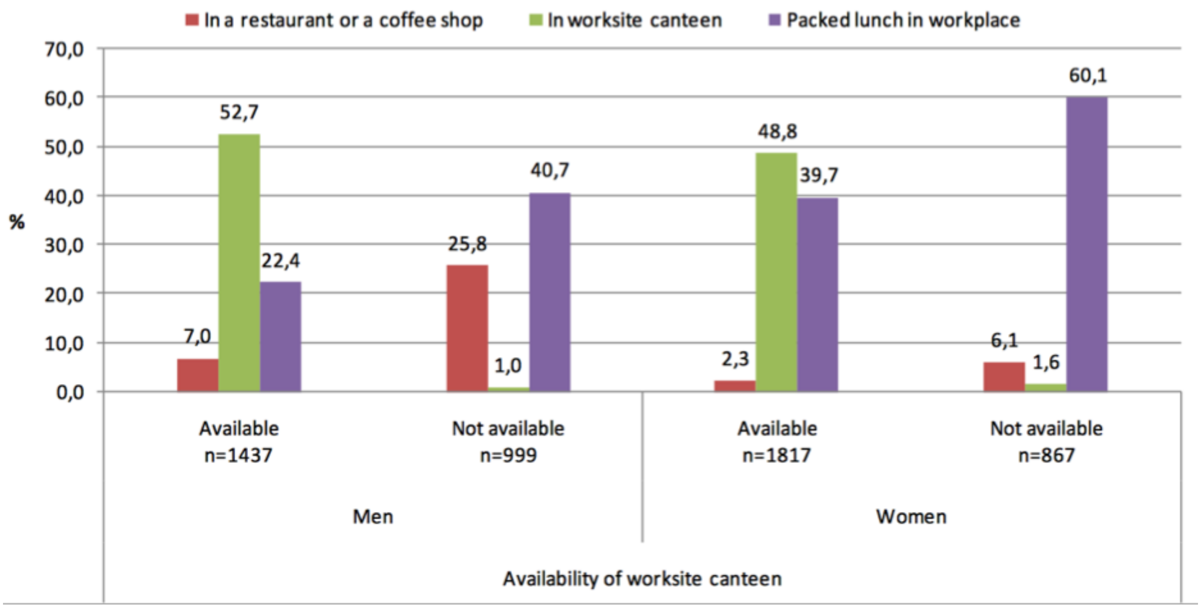

Figure 22: Lunch place choice by the availability of worksite canteen (Raulio 2011). The statistic is divided by gender, men on left and women on right, as well as by the availability of a work side canteen (available on left and not available on right). Furthermore, participants are divided based on where they eat their lunch and presented with coloured bars: in a restaurant or coffee shop (red bar), in the worksite canteen (green bar), or packed lunch at the work place (purple bar).

Schoolchildren eat mostly lunch at their school cafeterias too, as they get free lunch in Finland from first grade to high school every day (Albala 2011). Supported through the implementation of the new culinary culture strategy for 2009–2012, the development of the food choices in Helsinki during the last years invites nowadays more to get take-out food, street-food or go to a restaurant for dinner, rather than preparing it at home (Boyer et al. 2012). However, this is not a new development in Finland, even if the tradition of eating out is still quite young (Albala 2011). Through the economic boom, and the development of a generation with a new level of prosperity, the restaurant culture started to develop in Finland in the 1980s' (Albala 2011). Eating out was a new way to spend time with others, relax, and enjoy food, even in the middle of the week (Albala 2011). Even though recession in the 1990s', eating out as a social act had come to stay in Finland (Albala 2011). Therefore, still today eating out takes hold during the working week in Helsinki, not just at the weekend (Boyer et al. 2012). Already this lowers the residential water consumption per person, as 22% of the daily per person consumption comes from the kitchen duties in Finland (Lähteenoja et al. 2007). In addition to that the share of the daily per person consumption for toilet is in average 26% in Finland (Lähteenoja et al. 2007). When people do not spend their whole day at home, those consumptions are transferred into another water consumer category (e.g. public institutions, office buildings). Therefore, those are not counted in the residential water consumption category, and this leads to a lower average per person consumption. On the other hand, older people spend more time at home and due to their state of health they use more frequently the bathroom, which calls for a higher need of water (Schleich & Hillenbrand 2009). Another fact, which could not be studied in this work, is the influence of the outdoor water use. Outdoor water use is also accounted for the residential water consumption. The literature has different opinions about the used amount for outdoor activities. Corbella & Pujol (2009) analysed that families, with children or teenagers are the highest consumer group, which is generally due to the outdoor water use in Barcelona, Spain. On the contrary, Schleich & Hillenbrand (2009) stated that older people are the higher consumer group, inter alia, due to their higher outdoor water use for gardening. The factors behind behaviour are complex as the stage in live, circumstances as well as the experiences of a generation differ from each other and within an age group. Nevertheless, these were the most common explanations related to consumption and age.

In this study, the average age of the household in connection to the building age was analysed. Results showed, that the average age of people living in newer houses was 31. This also lowers the household water consumption due to the new and water saving devices, and leads to a lower average consumption per person (Agthe & Billings 2002). This is another explanation for the lower consumption of the households with a lower average age. Due to the construction year of the building the groups with a lower average household age seem to be more water conserving than the groups with a higher average household age. Moreover, the attitude to water conservation, the living area, the things parents teach their kids, the historical events in the centuries the people grow up in, the housing type, and the income among other things play an important role on the consumption depending on the age (Willis, Stewart, Panuwatwanich, et al. 2011; Inman & Jeffrey 2006; Russell & Fielding 2010; Randolph & Troy 2008; Billings & Day 1989).

The results of the analysis were just based on the average household age, which makes it even harder to give a reliable statement about the consumption behaviour as the assumption was, that a low average age is connected to families with young children or young people living together. However, it is still impossible to say, based on those results, if there is a difference between families, singles, or flat-sharing communities. Therefore, questionnaires could be hand out in the future by HSY to collect information about the consumption behaviour of the people in residential buildings as for now, the results can just be used to assume a tendency. These questionnaires could be done once a year, and stored in a database to use it as an additional information later. Moreover, the selection of a certain number of participants, who keep a consumption diary for a certain amount of time, can help to study the usage behaviour of the individual, depending on the age of a person.

5.1.3 Water Demand – Household Size

The per person consumption was highest in single households, 193.68 L/cap/d in 2014. In to 2-person-households the consumption was 137.01 L/cap/d in 2014, which is significantly lower than in single households. This result corresponded with results from the previous studies (Hummel & Lux 2007). With the increase in the household size, the water consumption per person decreases (Arbués et al. 2003). The difference to bigger households does not occur because single households use more water for the various water uses. It is more likely influenced by the fact that the water use in bigger households is more efficient (Hummel & Lux 2007). The increase of people within a household leads to the result that the needed amount of water for various water uses increases proportionally less than the number of people living within a household (Schleich & Hillenbrand 2009). The example of the consumption values (2014) in figure 10 confirmed the statement of Schleich & Hillenbrand (2009).

The age of the inhabitants can be another influencing factor on those results. Older people in urban areas are more likely living alone compared to the older people in rural areas (Eurostat 2015a). In 2015 the number of people in the age 65 and older living alone was >15% in Finland (Eurostat 2015b). The majority of older people in Finland lives in owner-occupied homes (Dedering & Henning 2013). The share of the people aged 75 and older, which live in ordinary houses, is 90% from which nearly 80% own their home (Dedering & Henning 2013). Ordinary houses include all types of residential buildings, which are not covered by any special legislation (Dedering & Henning 2013). This information connected to the analysis results of the consumption depending on building age, as well as the age distribution in those buildings suggest that water consumption of older people is higher because they live alone. However, this is just an assumption, which cannot be proved with the prepared analysis results. According to the theory the consumption should decrease with the size of a household (Russell & Fielding 2010). Nevertheless, the analysis results showed that the lowest consumption was found for the group with 5-6 inhabitants in the household. This could be connected to the amount of input data, but a look at table A 9 in the appendix 8 shows that the smallest consumer group were the households with 11-14 people. Another reason could be that the property was maybe marked as a single-family building but more families or renting parties do live in that house. Big family sizes are not common in this day and age (Figure 23), hence the maximum of 14 inhabitants accounts just for a few cases (see appendix 8, table A 9). Therefore, including the two groups with more than 6 inhabitants cannot be correct, and falsifies the results. Checking the number of data input points (see appendix 8, table A 9) confirmed this assumption too. From the group of households consisting of 3-4 people onwards, the number of input data points was decreasing. This decrease in data points confirms that the household size maximum should be set at six people per household to minimize the error. For reliable results, it will be necessary to gather information about the accurate household sizes, which could be also possible through the usage of questionnaires.

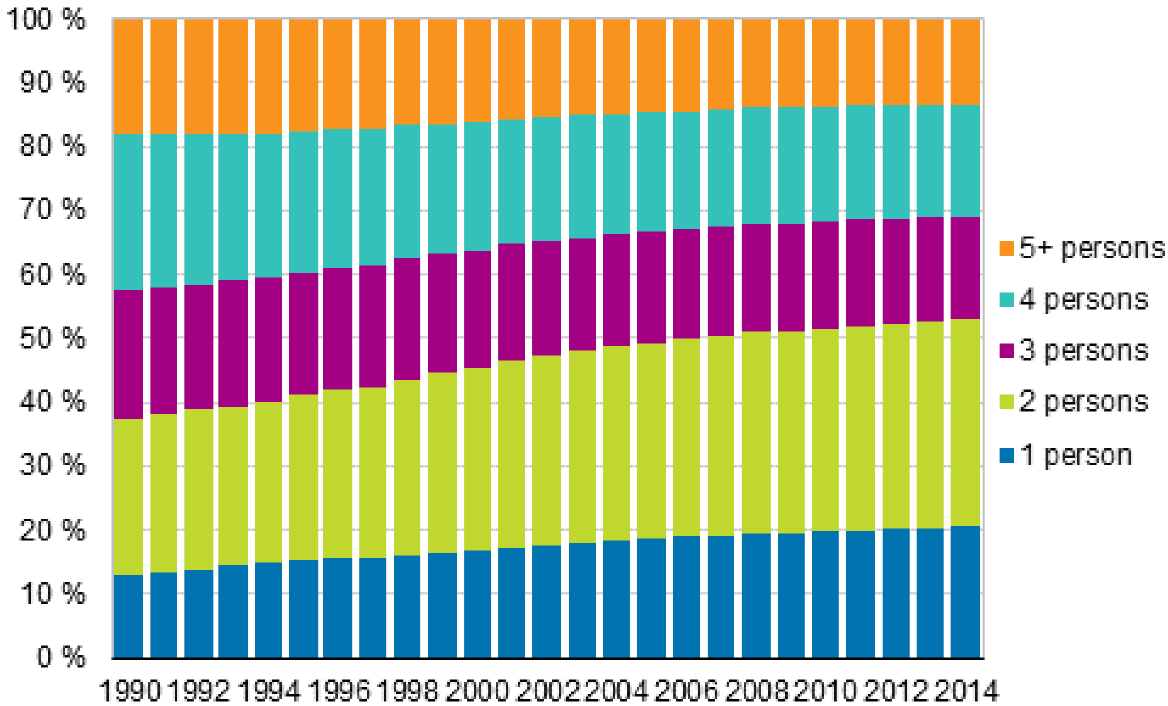

Figure 23: Household-dwelling unit population by size during the period 1990–2014 (Official Statistics of Finland 2014). The share of people living in a one-person household is presented with blue, two persons' households with green, three persons' households with magenta, four people households with cyan, and five or more people households with orange.

The future trend will be that the number of single households increases (Figure 23), and therefore the total residential consumption increases also (Official Statistics of Finland 2014; Willis, Stewart, Panuwatwanich, et al. 2011). The number of input data points of the single households increased already during the observation period from 1816 single households in 2004 up to 3403 in 2014 (see appendix 8, table A 9). With the help of an improved analysis and a forecast of the single household development, this factor should be implemented in the consumption forecast.

5.1.4 Water Demand – Building Age

From figure 11, a decrease in consumption for the buildings built between 1950-1964, and 1980-1989 can be seen. This can be connected to possible renovations of the buildings during the observed years, as renovated houses are supposed to consume less water (Agthe & Billings 2002). Figure 24 shows that from 40 buildings of 125 observed buildings constructed in 1960s' had pipe repairs already in 2010. Therefore, it is the category with the highest number of pipe repairs, which is followed by the buildings constructed in the 1970s' (34 pipe repairs), and the buildings constructed in the 1950s' (29 pipe repairs). This confirms at least the results of the construction decade 1950-1964.

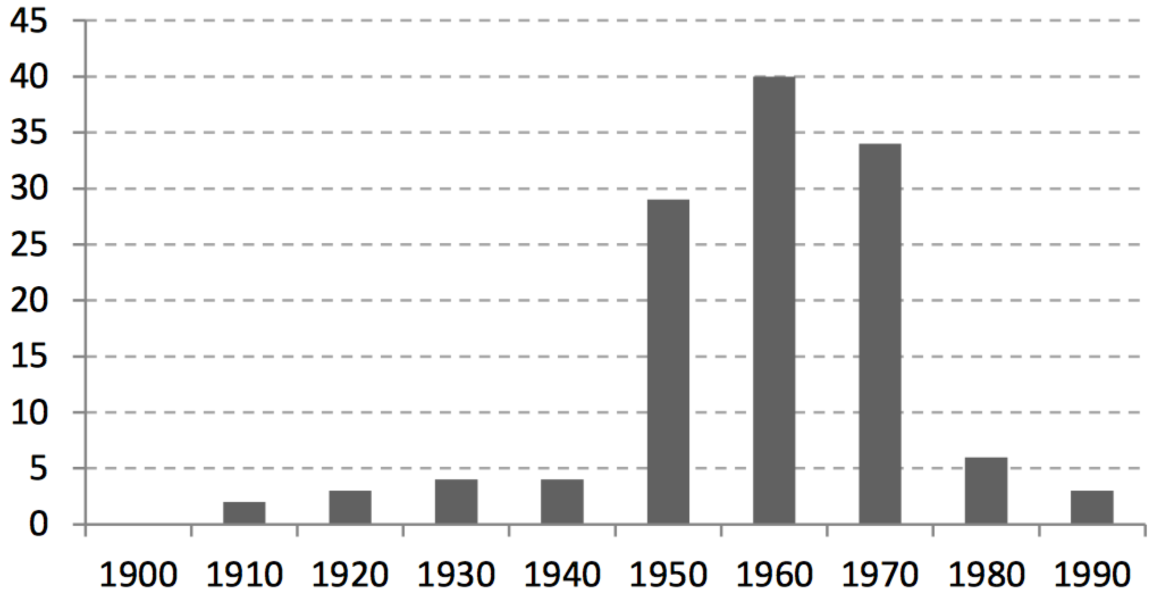

Figure 24: Latest pipe repairs by the construction decade of the building (Nikola 2011). The chart presents the distribution of latest pipe repairs by the construction year of the building on x-axis. The values at the y-axes indicate the repairs done in the last 10 years, while the total number of observations is 125.

Renovation does not always mean the total replacement of old devices. It can also include the installation of new devices into an excising structure (retrofit). According to Inman & Jeffrey

(2006), replacement of household appliances with more highly efficient appliances are more efficient compared to replacements. Therefore, the decrease in consumption for the buildings built between 1950-1964, and 1980-1989 can be connected to replacements. On the other hand, the buildings with the construction year between 1900-1949, and 1965-1979 have the highest water consumption, which can be connected to either outdated renovations in form of replacements or retrofitting programs. Nevertheless, figure 24 shows that already 34 buildings constructed in the 1970s' had pipe repairs. Therefore, the result for the group 1965-1979 should be lower than calculated. It can be assumed that other aspects than renovation, which were not identified in this research have an influence on the higher consumption.

Another aspect is the type of ownership. Homeowners are more aware of their water consumption and therefore more open to install water conserving fixtures to improve their homes compared to tenants (Billings & Day 1989; Randolph & Troy 2008). Due to the lack of information about the status of owning or renting the included buildings, this statement could be confirmed with the help of questionnaires in the future.

No matter how willing the owners or tenants are when it comes to the usage and installation of water saving devices, the saving potential through renovation and water saving devices will be almost exhausted at some point (Kluge et al. 2014). In the future all the buildings will be renovated and updated with the newest techniques, therefore the consumer behaviour is expected to be fairly stable in the foreseeable future (Kluge et al. 2014). Only moderate declines in the per capita water demand occur (Kluge et al. 2014). These accounts at least for the western countries, as we have our standards towards living and hygiene (Willis, Stewart, Panuwatwanich, et al. 2011). Following the only possibility to conserve more water, is through the change of the own thinking, behaviour, and governmental regulations (Willis, Stewart, Panuwatwanich, et al. 2011). The significant lower consumption in the buildings constructed after 2000 was implemented in the forecast calculations (see section 3.3.3).

5.1.5 Water Demand – Water Meter

The aim of this analysis was to see if the regulation changes in 03.01.2011 already showed an effect at the blocks, and terrace houses in form of an decrease in consumption (Finnish Ministry of the Environment 2010). Starting point was the statement found from the literature. Based on that, water metering on building level provides no economic incentive for occupants of the apartment to change their water usage behaviour (Agthe & Billings 2002). Water metering on building level can lead the occupant to lose track of the value of clean water and in many cases even to see water as a free good (Agthe & Billings 2002). The knowledge about individual consumption, and consumption-based billing have an impact on water usage behaviour of the customers (Billings & Jones 2008). According to Inman & Jeffrey (2006) the specific knowledge is significantly related to a lower demand and was shown to be more important than customers' beliefs about water conservation in reducing water consumption. Therefore, the consumption of the blocks, and terrace houses in the group with the construction year 2011-2014 was expected to be lower compared to the groups 1980-1989, 1990-1999, and 2000-2010. There is a strong variation within the results for the buildings built in 2011 and after. From 2011 to 2013 the consumption was increasing, and then decreasing again in 2014. Even the group of buildings constructed between 2000-2010 had a small increase in consumption. Especially after 2011 the results did not show the expected decreasing trend as in the literature. Therefore, an additional analysis of four blocks with installed individual meters was made (Figure 13). Also, this analysis showed a strong variation within the observation period (2011-2014). Only the two blocks within Helsinki, which had plumbing renovations in 2012 (C), and 2013 (D), showed a decreasing trend in consumption. If due to the plumbing renovations the tenants within the blocks had not changed they had realized the difference between paying a fee and paying the metered consumption, and that led to a more water saving behaviour. The amount of background information for this analysis was too small to hand out reliable results. This fact can be seen in figure 12, and figure 13, the number of data points in each group (see appendix 8, table A 11), as well as the statistical evaluation (see appendix 7, table A 7). Another fact is, that the period between installation and analysis is too short to get reliable results, and that the law still leaves room for decisions, especially when it comes to the billing based on the demand. For the future analysis of this influencing factor, it would be necessary to create a databank with the information of the status of installation and usage of the individual meters.

5.1.6 Water Demand – Income

According to the literature, low income households consume less water if they are billed based on their actual consumption (Agthe & Billings 2002). The consumption increases when the family income rises (Billings & Jones 2008). According to those statements, there should be a connection between consumption and average income level after 2011. The expectation was that the consumption increases with an increase of the average income. The other possibility is that the current price signal is not strong enough and therefore allows a voluntary behaviour based on the personal financial capabilities (Corbella & Pujol 2009; Inman & Jeffrey 2006).

First the average per person consumption in comparison with the average income on district level was observed. The results showed that the average per person consumption is almost the same within the districts (Figure 14). Compared to the average consumption of 158.06 L/cap/d of the other six districts in 2011, the Keskinen suurpiiri differed with a higher consumption, 253.27 L/cap/d. The reason for this difference was not concluded. The reason that no certain effect can be seen by displaying the results on district level, might be influenced by the equality policy in Finland. The bigger districts (suurpiiri) are mostly a mixture of low, medium, and high income districts. The current districts, were defined on the 13.12.1982 by the city council, and there is no information available about intention how they were formed (Wikipedia 2017). However, a study about the "Strategy Programme 2013-2016" was published by the City of Helsinki (2013), which confirms the intension that the city government and planers have the goal to implement diversity and equality through the city, without building any social peripheral regions. A look at the consumption in each income group (Figure 15) showed that in 2014 consumption slightly increased as the income increased. But as already mentioned in section 5.1.5, the observed period was too short, and the information inconclusive to get a reliable result. Nevertheless, the results are not just connectable to the inappropriate input data. On reason why there is no strong connection between income and consumption is that the income also effects the housing choices (Nikola 2011). Therefore, people with a low income live in apartment buildings, where they pay a certain fee per month, and lose track of the value of clean water, or even see water as a free good (Nikola 2011; Agthe & Billings 2002). Another reason for those results was the number of input data. A look at the number of the used data (see appendix 8, table A 12) shows that the included number of people and districts variated between 2008 and 2014. As an example, the income group of 75.000–100.000 €/cap/a included just five people in 2008, while the number increased in 2014 up to 2102 people. This shows that this analysis needs some improvements in the future.

5.2 Forecast

The prepared forecast shows one way how the consumption might develop in the future. The by Kluge et al. (2014) prepared forecast for Hamburg for example included five different scenarios, e.g. how the population development can influence the demand in the future. Based on those forecast results a maximum and minimum in consumption can be set, within which the utilities can operate their water supply system in the future.

The total consumption in Helsinki increased in the forecast in municipality and district scale. The per person consumption on the other hand was continuously decreasing. The difference was the amount in each forecast, by which the total consumption will increase, and the per person consumption decrease in the future. To include the increase of the population too, the assumption was that all new people are moving into new houses. Therefore, the building development was as well indirectly included. Based on the provided data and analysis results, just the average consumption of the new buildings constructed in 2010-2014 was included in the forecast. The advantage of the forecast on district level is that HSY can estimate the districts with the highest water consumptions in the future, as well as the difference to the actual water consumption. Therefore, they are able to react on possible changes.

The forecasted increase in population, and the applied assumption that all new people move into new houses led to the result that the per person consumption is continuously decreasing (Vuori & Laakso 2016; Laakso & Kilpeläinen 2015; Manninen 2016). The period for the saving potential of renovations and water saving techniques was not considered in this forecast. It needs to be emphasized that this effect will not last forever, therefore an appropriate period for the saving potential needs to be considered. It would be also necessary to know when the main renovations were or will be performed. If a cooperation with the renting and broker companies of the metropolitan region can be achieved in the future, it will be possible to implement other important aspects in the analysis (see section 5.1). Another aspect is the assumption that all new people move into new houses, and therefore reduce the future consumption. Based on this, the different aspects defining the population growth (e.g. growth through immigration) were not considered, as the number of new people does also includes new born. The daily consumption of a baby or child is lower than consumption of a grown-up person, and would therefore influence the results (Schleich & Hillenbrand 2009). This is not just an aspect from the literature, as it was also validated through the analysis results (see 4.1.2). It might be also favourable to include the consumption decrease due to building development.

Therefore, it would be good to know the future dwelling development corresponding to the forecasted population development. Moreover, it would be also interesting so see the development on the actual numbers of new constructed houses, as mentioned.

The second aspect, connected to that topic, which should be also included in the forecast, is the progress of renovation. As the information, which influenced certain categorising decisions and interpretation of the results, was based on insecure information gathered from broker websites (Oikotie), no trend in renovation development was available for the future. However, if the information was right the consumption decreases in the building category marked as renovated. This will also effect the future consumption.

Furthermore, the information about the development of the consumption depending on the increase of single households would be important, and interesting. Already the actual number of households included in that category increased during the observation period (see appendix 8, table A 9), and it is predicted to continue like this (Official Statistics of Finland 2014). Another interesting aspect for the future would be the influence of the development of the individual water meter regulations on the consumption, which also could not be included to this analysis.

The prepared forecast is just a simple way to implement the results in combination with the population forecast produced by each city authorities. There are more improved and reliable ways to forecast the consumption, but a forecast like that needs more detailed input data, and a forecast-model. This acquires a lot of extra work, knowledge, data, and appropriate programs, which cannot be done within the scope of this work. However, it can be said for sure that with the forecasted population development, the total consumption will increase and the per person consumption decrease. The per person decrease is supported by the savings through new saving devices and renovations.

6 CONCLUSION

In the last part of this work, the research is summarised, and the possibilities for practical implementations of this work, the limitations, and the suggestions for future research in the metropolitan region Helsinki are presented and discussed.

6.1 Research Summary

The aim of this work was to analyse the influence of certain factors on the residential water consumption in Helsinki and Hamburg, to create a comparison based on this, and to implement the results in the forecast of the future demand. Considered influencing factors were the age of the residents, the household size, the construction age of the building, the water metering, and the average income of the residents.

Starting point for this work was the course work from Ahopelto et al. (2015) for HSY, with the goal to extent the scope of that work, and to compare the situation in Helsinki, Finland with Hamburg, Germany. Based on the legal data protection regulations of the Water company of Hamburg (HWW) just the data of the average price development, as well as the total consumption for the period 2004-2015 was provided.

According to the results of the studied reports, e.g. Billings & Day (1989), Agthe & Billings (2002), and Russell & Fielding (2010), the influence of each of the implemented factors should have been visible in the analysis results. Therefore, a strong relationship between the studied factors and the consumption was expected. The only factor with different conclusions within the literature was the population age. Starting with an overview of the total residential and per person consumption, a clear decreasing trend for Helsinki, and a slightly decreasing trend until 2008 followed by an increase for Hamburg was observed. The results of the analysis of the population age did not show a clear trend between 2004 and 2014, but a clear difference in the consumptions between the age groups in each year was found. According to the results, the consumption of the younger people was lower compared to the consumption of older people. An important restriction in this analysis, which needs to be mentioned, was that the implemented age was the average age of the household. Therefore, the assumption was that within a household with a low average age probably lived children, and that the age of the adult tenants is low. Compared to that, a high average household age implied that the inhabitants are older, and maybe already retired. The results gave an idea about the differences in usage behaviour between younger and older people. Due to the restrictions, the real consumption within the age groups is still unknown. In addition to the consumption in each age group, the average age of the tenants in connection to the construction year of the building was analysed. The results showed that younger people lived in newer buildings, which might be an explanation for the lower consumption in the lower age groups.

The next factor was the consumption according to the household size, which was highest in the single households, as expected. Then the consumption decreased when the household size increased, until a maximum of six tenants. Following the consumption increased again in the groups with more than six household members. The effect can be connected to the fact that a household with more than six household members is in this day and age quite rare (Official Statistics of Finland 2014). Again, there was no clear trend in the data visible.

At next, the influence of the construction age was analysed. This category is the only one, showed a decreasing trend since 2004. It was calculated that buildings constructed between 1900-1949 (138.40 L/cap/d)[9], 1965-1979 (139.60 L/cap/d), and 1990-1999 (134,04 L/cap/d) consume more water than the rest. The most significant decrease was seen for the buildings constructed in the 80s', which can be connected to ongoing renovations. For the buildings built between 1950-1964 and 2000-2014, the lowest consumptions were calculated. Therefore, the fact that new buildings (2000-2014) consume less needed to be included into the forecast. The low consumption in the buildings constructed between 1950-1964 can be connected to the pipe repairs (Nikola 2011).

The influencing factor water meter type was included based on the law changes in Finland in 2011. Since the beginning of 2011 individual water meters need to be installed in new or renovated buildings, but the use is not mandatory. Even though installing individual meters is compulsory, billing based on them is not (Finnish Ministry of the Environment 2010). This loophole was also seen in the results. Before 2011 the consumption of the tenants of terrace houses and blocks was metered with the help of a common meter, and billed through a certain fee, which was mostly included in the rent. By checking the consumption of terrace houses and blocks built in 1980-2010 and from 2011 onwards, the intension was to see an effect in the consumption because of the law change in 2011. However, the results showed, especially

[9] Consumption in 2014

for the important category of buildings constructed in 2011 or later, a strong variation and no clear decreasing trend, as expected. Furthermore, the results for this factor were based on the short observation period and the small number of data, so they are not reliable and do not bring a benefit for the study.

The last considered factor was the income. According to the literature, there is a connection between income and consumption when people get billed based on their individual consumption (Willis, Stewart, Panuwatwanich, et al. 2011). Therefore, the years 2008, 2011, and 2014 were chosen with the intension to compare the consumptions before the law change, in the year of the change, and after the law change on district level, and within different income groups. On the district level a relationship between income and consumption was not analysable. However, the results within different income groups showed a slight increasing trend in consumption when the income increased. The observed period was too short and the information inconclusive to get a reliable result. This shows that this analysis needs some improvements in the future.

To prove the reliability of the results, a linear trend in data was estimated. The performed statistical evaluation showed diverse results. The best fit was achieved for the analysis of the construction year. Reasons for the partly unreliable results are data gaps, a small amount of input data in some research categories, and the way how the data was prepared to implement in the analysis. The water consumption until 2025 in the city districts of Helsinki, and the consumption until 2040 of the metropolitan region Helsinki was forecasted by taking into account the analysis results of the influencing factors and the prepared population forecasts (Laakso & Kilpeläinen 2015; Manninen 2016; Vuori & Laakso 2016). The forecast was performed in two different ways, which both showed similarities in the result, increase in the total residential consumption, and decrease in the per person consumption. Reasons are the increase in population, the saving potential due to renovations of old buildings, and the usage of water efficient technologies in new and renovated buildings. This applied for the districts as well as the metropolitan region.

Overall, the results of this study can give an idea and overview about the past, current, and future water consumption in Helsinki. They showed also that, based on political regulations, some of the influencing factors did not really influence the consumption. This accounts for the consumption depending on the water meter (common/individual), and based on this also for the income.

6.2 Practical Implications

The practical implication of this work can be used on a local as well as on a national scale. While the results itself are useful for HSY, the implementation process can be also adopted elsewhere in Finland or Europe. As this detailed analysis of the influencing factors is the first one of its kind in Finland, the concept could be implemented in other cities and regions too. This way utilities can get an overview of their current and future situation as well as have a chance to react according to that, if it is necessary.

The analysis and forecast results can be used by HSY to get an overview about the current situation, as this way of analysing the consumption has not been performed yet in the supply area. This new perspective can help to better understand the processes and drivers for the consumption, and so maybe adjustments to the system can be made if necessary. On the other hand, the implementation process showed some lacks in the provided data sets, e.g. missing property code for water consumption, and renovation status of the buildings (see section 3.1.6). Based on this, HSY has the possibility to improve their data collection system so that it can be used to run this analysis again in the future. However, to do so, the collection system needs to be improved and data gaps filled as the reliable data is the important basis for the analysis.

The developed mix method approach consists out of easy to use programs, so therefore the concept is easy to implement. The disadvantage is, that a certain type and amount of data needs to be available. However, if those or similar data sets do exist the improved version of this concept can be implement by other utilities. Therefore, extra costs can be saved for hiring an external institution to perform a similar analysis.

6.3 Limitations of the Study

Probably the biggest limitation of this study was the length of the observation period, which is with 10 years enough to get the needed overview, but the data availability for a longer period is always an advantage when it comes to analysis and forecasting processes. The second limitation was the missing data for Hamburg. It did not have an influence on the quality of the work, but the former plan of the work to compare situations in Helsinki and Hamburg was not possible to be performed completely. Since in Hamburg the installation and use of individual meters is compulsory since 2006, the perspective of the work could have been changed due to this comparison (Zenner 2003). The third limitation were the input data itself, as the main parts of the data sets, which were necessary for the connection process and evaluation, were not equal in quality and quantity of information. It is necessary to revise the data so that they all have the same codes, include the same buildings etc. in the future. The connection of the data therefore showed that all residential buildings listed in the building data set are not linkable to a water consumption. After the data were displayed and their reliability checked, it was noted that the building, population, and businesses data sets included data points outside of the observed area. The reasons for this can be that the data sets were provided to HSY by the communities. Therefore, the usage of different codes by the institutions, and the listing of areas outside of the HSY supply area (e.g. Östersundom) led to data gaps and errors after the process of connecting the data. Moreover, most of the data were not allocated to corresponding district (suurpiiri) during the analysis of the influence of the income, as the district code (Kokotun) information for most of the data was missing. To avoid this mistake, the data gaps for the district code were filled with the information from the other years, if available. The last limitation of the input data was the missing property and building code for the water consumption data sets. Before the code was created, the errors in the data needed to be removed, which reduced the input data. Furthermore, the joining process using ArcGIS brought additional errors as the joining was done using the property code. The problem was that in some cases one property included more than one building, but just one common meter. To reduce the error the doubled consumptions needed to be removed, the number of tenants summed, and the average household age as well as the building age calculated. The data preparation process as well as the data sets need to be optimised in the future.

When it comes to the analysis, there was a limitation that the individual consumption of a person was not available. This was applicable on the one side for the individual consumption of the households in terrace houses as well as blocks, and on the other side for the consumption behaviour of each household member. The first limitation did lead to the fact, that it was not possible to include blocks and terrace houses into the analysis of the influence of the age and household size. The reason was that it cannot be said for sure how much each individual person consumes in those buildings, as mostly common meters were in use. Therefore, the metered amount represents the total consumption of the block. The lack of information about the consumption of each household member, did lead to the fact, that the average age of the household needed to be used, even if the amount of people within the age groups was available. Due to that, it was not possible to analyse the real consumption behaviour of the age groups like it was planned. This lack in information could be improved through the implementation of individual consumption diaries of volunteers. Another possibility would be the usage of yearly performed questioners about the water consumption behaviour of the customers. Moreover, the analysis of the difference in consumption between the two water meter types was limited by the lack of information about the water meter type. Therefore, in the future, it would be necessary to know in which blocks individual meters are installed, and if they are in use. The solution to gather this information could be a cooperation with the local renting and broker companies.

The limitation of the forecast was on the one side the aspect that the consumption development influenced by the development of single households was not implemented, and on the other hand that Excel was used to replace a complicated forecast model. The development of the single households can be probably provided by the city of Helsinki, which also prepared the used forecast “Helsinki and Helsinki Region Population Forecast 2016–2050” (Vuori & Laakso 2016). Based on the limited function options in Excel, it can be that a different software needs to be considered in order to meet the future requirements.

One other aspect, which influence was not possible to be proven, was the formation of HSY during the observation period in 2009 (Ahopelto et al. 2015). That formation process may had influenced the data collection process. The assumption is based on the observation, that in the analysis of the residential consumption the consumption drops significantly after 2008 (Figure 4). Another possible explanation could be that the decrease in consumption is consequence of the economic crises in 2008, which hit the Finnish economy hard (German Federal Foreign Office 2017). Both could be possible and would need more research in cooperation with HSY, in order to figure out the reasons, and to be able to take this effect better into account in the future analysis.

6.4 Suggestions for Further Research

There are possibilities to improve this work as it is the first one of its kind in Finland. One possibility, is to extend the scope of this study by including more influencing factors. Other interesting possibilities could be the analysis of the influence of the water price, the climate, and the attitudes towards environmental awareness, as well as the influence of political campaigns or law changes regarding environmental protection.

Moreover, the consumption of businesses located in residential buildings should be included in future studies. Especially in the centre of Helsinki most buildings have a mixed use between living and different kind of businesses (e.g. restaurants, stores, hairdresser). Therefore, the metered amount of the building needs to be divided into different user groups. Based on this, it would be interesting to include also other consumption groups into further research, as it would be necessary for the forecast to examine if the designed capacity of the waterworks is suitable for the total consumption of all consumer categories in the future.

The missing information about the water meter type and where individual meters are in use should be included in the future. First, the information provided by HEKA can be used, but there should be put effort to gather the same information from the other broker or renting companies too. Furthermore, the information gaps about the development of the single households should be filled in the future. With this information, the forecast can be improved, as the calculated difference between single households and multi-person households is huge, and the trend is an increase of single households. This was seen already from the analysis. Also, interesting would be a more intensive connection of the results to behavioural or psychological studies, to evaluate the motives of the customers behind the calculated consumption. Some psychological studies have been already included in the theoretical part, but based on the provided data an evaluation of the motives is not possible. As for this information questionnaires or individual consumption diaries would be necessary, just assumptions could be made.

For the evaluation of the forecasting results, it would be also necessary to gather information about the peak period consumptions during the week as well as the seasons. The seasonal changes are necessary if there is a significant change in the supply area. By using this information, it could be studied if the capacity of the waterworks is suitable in the future or if modifications in the design will be necessary.

The last suggestion would be to work on the implementing process of the analysis and the forecast in the future. As this was the first try to implement this kind of study in the metropolitan region Helsinki the process needs some improvements, to be more fluent. The handling of the software is simple, if the ready-made MATLAB codes are provided. Therefore this analysing and forecasting process has potential to be adopted also by others. To achieve this, it would be also necessary to create a new databank or to improve the existing one, which could be then a role model for other studies. Even if the current results partly have errors, the process itself has a potential to be adopted by other utilities to analyse possible starting points for reduction, to get an overview of the situation, and to forecast the future consumption without hiring an external company for this.

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8 APPENDICES

APPENDIX 1 – DATA PREPARATION

The first step was the data preparation, as the input data was not applicable for the intended purpose. The first step after acquiring the data was to create the property code (KIITUN) for the water consumption data out of the municipality code (Kunta tunnus), the village code (Kaup.osa/kylä tunnus), the block code (Kortteli/Rek.nro), and the registration code (Tontti/Rekisteri-indeksi). This was done, as already explained in section 3.2.3, with the help of MATLAB. First it was necessary to check the input data for errors (e.g. Tontti/Rekisteri-indeksi can have "0001 H"), since the prepared code can just handle 1-4-digit numbers. To be later able to join the water consumption data sets with the other data sets, it was necessary to save the created code as a TEXT-format in Excel-sheets. Through the deleting of data points, while checking for errors the number of costumers, provided through the input data, was reduced.

In the second step, all data tables were uploaded and visualize in ArcGIS as a new map layer by displaying the XY-data from the table. The input data was provided in different coordinate systems (Table A 1). All water consumption data (2004-2014) are in the EUREF-FIN coordinate system ETRS_1989_GK25FIN, while the input data for population and buildings until 2011 are in the National Grid – Finland Zone 2, the other years until 2015 have the same coordinate system as the consumption data. The reason for this is that in 2005 Finland started to change the projection of all topographic maps from the Finnish National Coordinate System to the EUREF-FIN coordinate system (Uikkanen 2013).

Table A 1: Overview of the used coordinate systems in ArcGIS

Input Data	Year	Coordinate System
Water Consumption	2004-2014	ETRS_1989_GK25FIN
Population Buildings	2003-2011	Finland Zone 2
Population Buildings	2012-2015	ETRS_1989_GK25FIN

All data sets were saved as a feature class in a geodatabase (gdb). Following the data was joined for each year and supplied city according to the following concept. First the population and the water consumption data sets were connected, based on the property code as a common attribute. Then the building data were added, through the building code. Before exporting the tables, the data was reduced by deleting unnecessary or doubled columns (Table A 2). Following the tables were exported as explained in section 3.2.2.

Table A 2: Overview of the content of the analysis data tables

Data basis	Abbreviation	Meaning
Population	KIITUN RAKTUN PKOO IKOO ASHYT IKA_KA IKA0-IKA85YLI KATU OSNO1 OSKI1	Property code Building code Y-coordinates X-coordinates People per building Average age Age from 0 to over 85 Street Street number Addition to address
Water Consumption	Xfield Yfield Kunta tunnus KIITUN_NUM KIITUN_TEXT Käyttötarkoitus nimi KATU Laskutettu vesi	X-coordinates Y-coordinates Municipality code Property code as number Property code as text Building purpose Street Consumption
Buildings	KIITUN RAKTUN PKOO IKOO KATU OSNO1 OSKI1 KAVU KATAKER KERLA KOHALA VI VJ ASLKM OMLAJI HUO1-HUO6_YLI ALA1-ALA6_YLI AS1-AS6_YLI	Property code Building code Y-coordinates X-coordinates Street Street number Addition to address Building year Building purpose Living space Living quarters Sewer (Yes/No) Water pipe (Yes/No) Number of housing units Ownership type Number of rooms Apartment block (room-based) Number of dwellings (room-based)

The data gap for the years 2004 to 2007 (see section 3.1.6) was closed through linear interpolation between 2003 and 2008. Therefore, the water consumption of the years 2004 to 2007 was joined with the columns: number of tenants (ASHYT), average age (IKA_KA), and building year (KAVU), from the years 2003 and 2008. The following interpolation process was performed with Excel.

The factor (x_{new}), by which the missing data was changing, was calculated according to:

$$x_{new} = \frac{x_{2008} - x_{2003}}{t_{2008} - t_{2003}} \qquad \textit{Formula A 1}$$

Following the factor was added to the processed data. The result was an increase or decrease, of the number according to the calculated factor (x_{new}). If the houses were built after 2003 it was assumed that the average age of the household, increased each year until 2008, and that the number of tenants did not change. The houses, which were not built in the examined years, were not included in the prepared tables. After this step, it was necessary to remove the duplicated water consumptions from the analysis input tables. Because of the joining of the water consumption data with the rest of the input data an error was created. The reason is the property code as a used common attribute. Some properties (KIITUN-Kiinteistötunnus) included multiple buildings (RAKTUN-Rakennustunnus), which are all metered together. Therefore, the buildings (RAKTUN) with the same property code (KIITUN) got allocated with the same metered value, which falsified the first results. Based on this it was necessary to summarise those buildings together on property level. In this way, the error of using one consumption two times was eliminated. The error was improved with the help of MATLAB. The code was checking the data set for duplicated property codes (KIITUN), in case the code exists multiple times, the number of tenants was summed, the average age was calculated, and the average building year as well. The average building age was only calculated in cases with different building ages. The rest of the necessary informations' (e.g. property code, and water consumption) were adopted from the input data. The new created data set was converted into a new Excel-sheet, which was in the end the input data set for the analysis of the drivers of residential water consumption. As the income data was not part of the data set provided by HSY it was necessary to develop a way to bring those two information sources together. The fastest and easiest way to connect the data was by using ArcGIS. An existing district shape-file was use for that. By adding a new field to the attribute table of the district shape-file, and filling it with the average income information of each smaller district the shape-file was updated for the needed purpose. Following this information was joined through the district code (Kokotun) with the analysis input data tables. Based on this all data points without a district code were deleted from the table, which lead during the first try to a decrease in the number of population, while it should increase. The reason was that the data points provided with a district code, information (Kokotun) decreased through the years. So, the developed approach needed to be changed. The ArcGIS approach stayed the same but following the data gaps in each year were filled with the missing information by using the Excel-filter-function. Means the district code, name, and average income were copied to the missing fields manually

Appendix 2– MATLAB-Code

The MATLAB-code for calculating the total consumption of the residential buildings according to their building types worked so, that all the data with the same building type were selected. Then, to calculate the total residential consumption, the consumptions of each building type were summed up, and subsequent converted from m^3/a into M m^3/a. This was done to improve the future legibility of the graph.

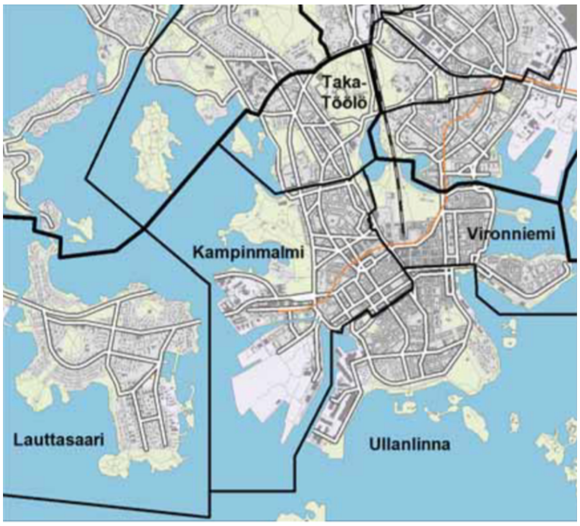
The code for the analysis of the influencing factors was built so, that a list was created which includes all data, e.g. with the age under and equal 25. Following the before calculated per person consumptions were summed and divided by the length of the list to receive the average per person consumption of that group. This was done for all the set groups and observed years. The same approach accounts for all analysed influencing factors.

The model statistics, created with the MATLAB fitlm-function, were stored in a mdl-variable. To make a statement about the reliability of the results, not all data from the mdl-variable were needed. So just the coefficient of determination (R2-values), and the probability value (p-values) were saved in a new Excel-sheet (see appendix 7, table A 7). Additional to the numbers, also graphs were created with MATLAB, to see the linear trend. The same approach accounts for all analysed influencing factors.

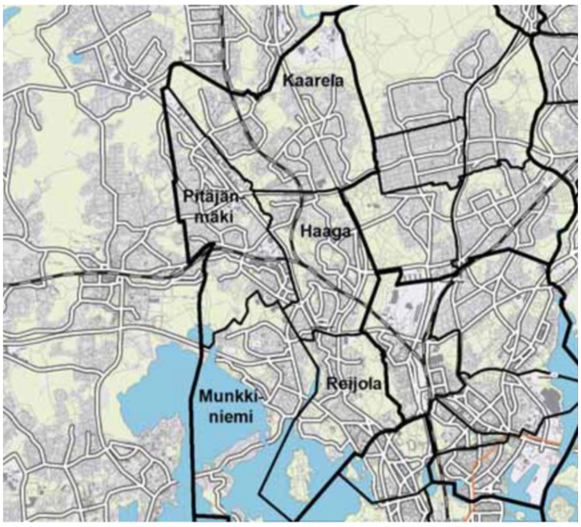
APPENDIX 3– DISTRICT MAPS

a)

b)



c)



d)

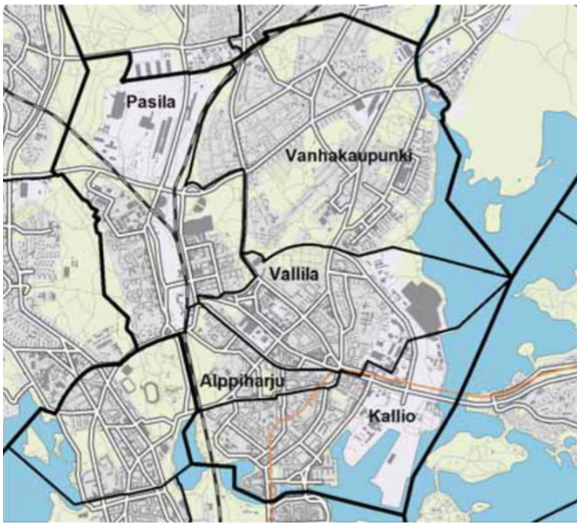


Figure A 1: Map of Helsinki with all 34 smaller districts and more detailed maps about the major districts (thick black borderlines) and the smaller districts (thin black borderlines) (Tikkanen & Selander 2014). Maps are marked with letters: a) City of Helsinki, b) Eteläinen suurpiiri (091 1), c) Läntinen suurpiiri (091 2), d) Keskinen suurpiiri (091 3).

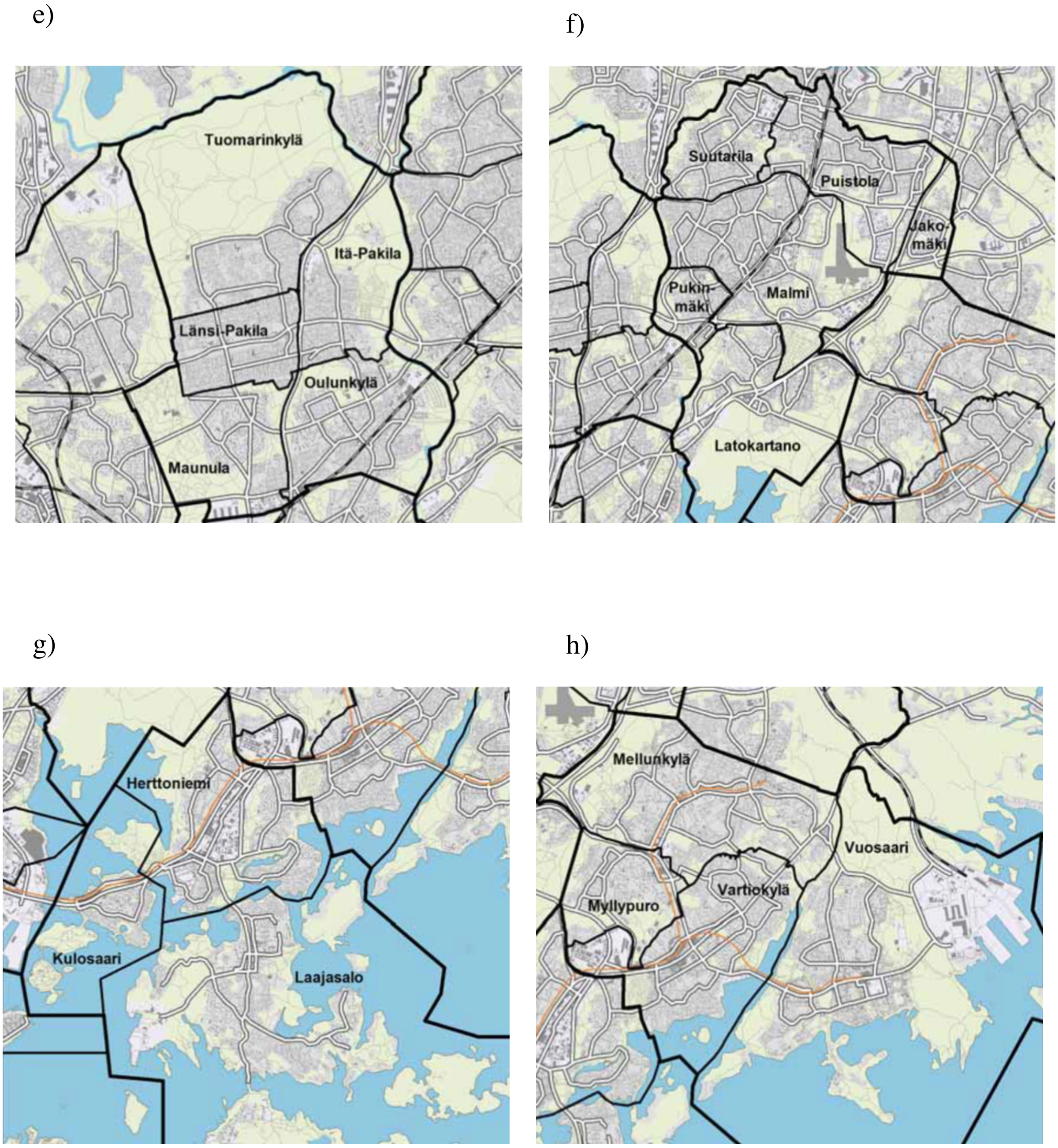


Figure A 2: Map of Helsinki with all 34 smaller districts and more detailed maps about the major districts (thick black borderlines) and the smaller districts (thin black borderlines) (Tikkanen & Selander 2014). Maps are marked with letters: e) Pohjoinen suurpiiri (091 4), f) Koillinen surpiiri (091 5), g) Kaakkoinen suurpiiri (091 6), and h) Itäinen suurpiiri (091 7).

APPENDIX 4– DEPENDENCY WATER CONSUMPTION AND EDUCATIONAL LEVEL

As an addition, the dependency between education and consumption was analysed. According to the literature there are two different opinions about the dependency between education and water consumption. Russell & Fielding (2010) referred in their report to two studies made by Gilg & Barr (2006), and Lam (2006), with the outcome that participants with a higher commitment to conservation were also the highly educated once. But they also referred to a study from Clark & Finley (2007), which detected in their results that lower educated households are more water conserving (Russell & Fielding 2010). They also focused on the relationship between specific knowledge of climate change impacts and water conservation behaviour, with the results that people which reported a greater awareness of climate change and global warming also reported greater water conservation intentions (Russell & Fielding 2010). Based on those results their conclusion was, that the usage of information about peoples specific knowledge about water conservation is better than using general measures of education, if peoples water conservation behaviour wants to be determined (Russell & Fielding 2010).

The educational level in the seven city districts was gathered with the help of the report "Helsinki by district (Helsinki Alueittain 2013)" (Tikkanen & Selander 2014). The education data (Koulutustaso) were date with the 31.12.2011, and no other report with this information was available. Therefore, this analysis was just created for 2011. The water consumption in the districts from 2011, calculated for the income analysis, was used for this one too. Just one year did not provide any reliable statement about the dependency, and a comparison is not possible. Therefore, this analysis was not presented in the main part of the report. But still this analysis was made and is another possible research factor for future research.

Table A 3: Overview of the educational level in the districts (Tikkanen & Selander 2014)

		Educational Level in 2011 *			
		Comprehensive school level	Senior secondary school level	Vocational and professional education level	University Level
091 1	Eteläinen suurpiiri	15,994	26,973	21,654	26,366
091 2	Läntinen suurpiiri	23,689	30,145	20,513	16,123
091 3	Keskinen suurpiiri	17,997	28,617	16,376	12,430
091 4	Pohjoinen suurpiiri	9,819	10,125	7,762	7,098
091 5	Koillinen surpiiri	26,428	28,026	15,841	8,666
091 6	Kaakkoinen suurpiiri	11,728	12,712	8,497	7,211
091 7	Itäinen Suurpiiri	33,227	30,264	15,542	8,205
* include all people over 15					

In table A 3 there are the number of people in each of the four educational levels in Finland listed for each of the seven districts. The first possibility to graduate from school is after finishing the comprehensive school level (Enintään perusaste), this is followed by the senior secondary school level (Keskiaste), and then the two highest levels of education are the vocational and professional education level (Alempi korkea-aste), which gives the opportunity to attend the universities for applied science, and then the university level (Ylempi korkea-aste). All listed numbers include all people over 15. The results, which are presented in figure A 3, were like the results of the dependency between income and consumption in the districts. Means there cannot be drawn a connection between the educational level and the consumption on district level. Quite significant was, that the number of people having an education on university level was highest in the Eteläinen suurpiiri, and decreased in the following six districts. Also significant was that the number of people having an education on the senior secondary school level was the highest number in each district. Depending on the district the second most common educational level did variate.

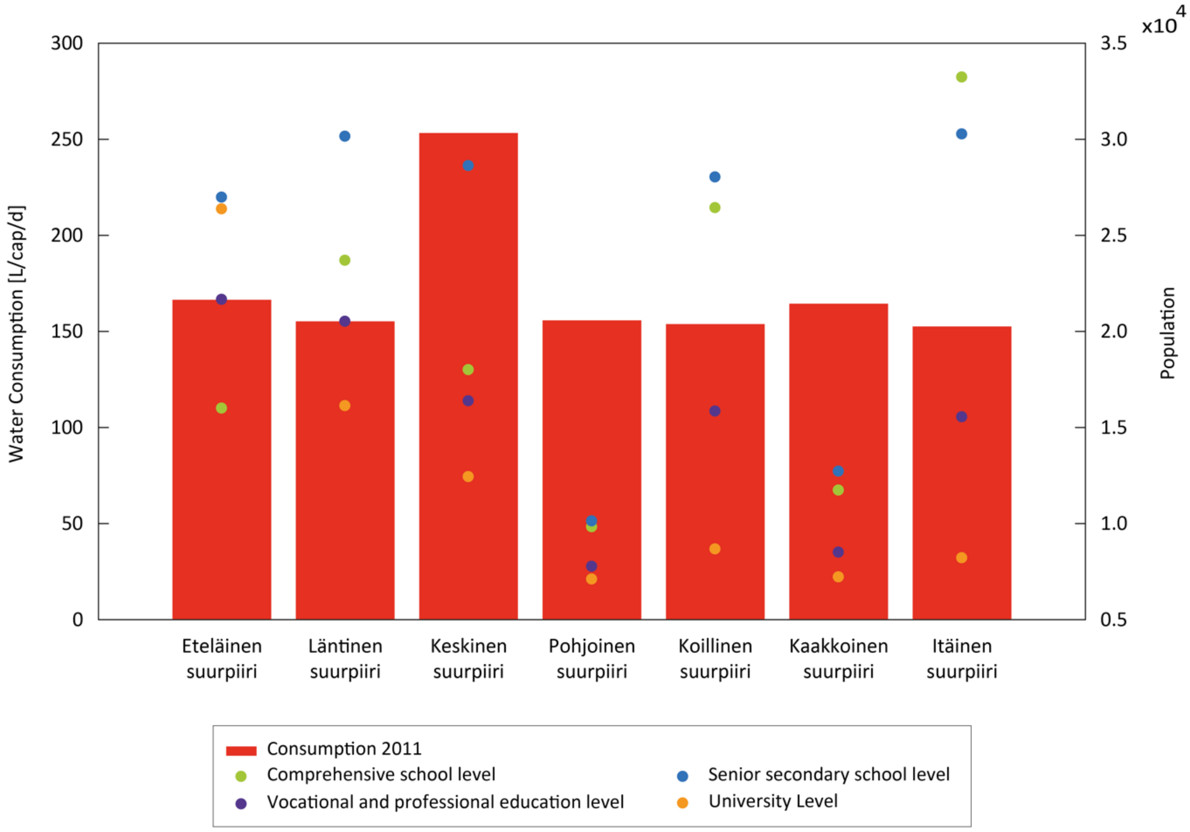


Figure A 3: The dependence of the water consumption (L/cap/d) and the education level for the city districts (suurpiiri) of Helsinki for the year 2011. For each of the seven districts on x-axis, the consumption is presented with red bars and the educational level with coloured dots: comprehensive school (green), senior secondary school (blue), vocational and professional education (purple), and university level (orange).

As mentioned earlier, there was no connection between education and consumption, if the consumption was divided on district level. This was already seen for the income analysis on district level. Observing the consumption per person in each education group would show different results. But with the actual data this division was not possible. To be able to implement that, it would be necessary to gather the educational level from each HSY customer. This could be realized with the help of questionnaires. Probably also the fact that people with a lower income have a lower educational level (Table A 4), and need to live in rental dwellings (e.g. blocks) where people do not pay their water according to their own consumption leads to those results (Official Statistics Finland 2011; Nikola 2011). Therefore, it can be summarised that the analysis gave an idea about the current situation, but it did show more what should be done to improve that analysis for further research.

Table A 4: Average monthly pay of full-time wage and salary earners by fields of education and educational levels[10] in 2011 (Official Statistics Finland 2011)

Classification of Education	Educational level				
	Upper Secondary Level Ed.	Lowest Level Tertiary Ed.	Lower-Degree Level Tert. Ed.	Higher-Degree Level Tert. Ed.	Doctorate Level Tertiary Ed.
1 Teacher Ed., Educational Sc.	2 993	2 891	2 940	3 521	4 703
2 Humanities and Arts	2 441	2 887	2 868	3 491	4 371
3 Social Sciences and Business	2 612	3 077	3 269	4 678	5 174
4 Natural Sciences	2 856	4 232	3 691	3 961	4 564
5 Technology	2 866	3 677	3 870	4 691	5 274
6 Agriculture and Forestry	2 538	3 064	3 026	4 223	4 822
7 Health and Welfare	2 408	3 002	2 749	5 534	6 671
8 Services	2 399	3 187	2 991	4 245	4 777

10 1. Upper secondary level = 11 to 12 years in education.

2. Lowest level tertiary education = 2 to 3 years of education after upper secondary education

3. Lower-degree level tertiary education = 3 to 4 years of education after upper secondary education

4. Higher-degree level tertiary education = 5 to 6 years of education after upper secondary education (Official Statistics Finland 2015)

APPENDIX 5 – THE POPULATION INPUT DATA FOR THE FORECAST

Table A 5: Population data for the forecasted years of the cities Helsinki, Espoo, Vantaa and the metropolitan region (Vuori & Laakso 2016; Laakso & Kilpeläinen 2015; Manninen 2016)

Year	HSK	Espoo	Vantaa	Metropolitan Region
2015	620,715	265,543	212,470	1,098,728
2020	654,599	286,807	228,719	1,170,125
2025	683,487	304,866	244,935	1,233,288
2030	709,430	321,823	257,756	1,289,009
2035	725,768	337,740	268,535	1,332,043
2040	737,019	353,264	277,988	1,368,271

Table A 6: Population data until 2025 for forecast of the consumption in the Helsinki city districts (Vuori & Laakso 2016)

Year	Eteläinen	Läntinen	Keskinen	Pohjoinen	Koillinen	Kaakkoinen	Itäinen
2015	108,210	106,287	88,651	42,218	97,543	48,971	107,957
2016	109,802	107,131	90,140	42,766	98,673	49,354	109,425
2017	111,616	107,839	90,716	43,177	99,275	50,727	110,502
2018	113,210	108,479	91,029	43,343	101,058	51,936	111,568
2019	114,996	109,440	91,273	43,595	101,375	53,680	113,115
2020	116,169	110,339	92,340	43,800	102,053	55,354	114,439
2021	117,028	110,961	93,974	44,116	102,607	57,296	115,538
2022	117,780	111,814	95,763	44,265	102,783	58,950	115,943
2023	118,992	112,561	98,014	44,494	103,145	59,653	116,182
2024	120,093	113,419	99,926	44,788	103,512	60,671	116,356
2025	121,444	114,160	101,883	44,886	103,637	61,879	116,396

APPENDIX 6 – FORECAST PART II

The important results of the forecast were already presented in the main part of this work. In this appendix chapter the forecast results for the three cities are presented to get a better idea for the changes of the water consumption.

a) City Helsinki

A closer look to the city Helsinki showed for both forecast versions an increase of the total consumption, and a decrease of the per person consumption. Also, here the amount did differ.

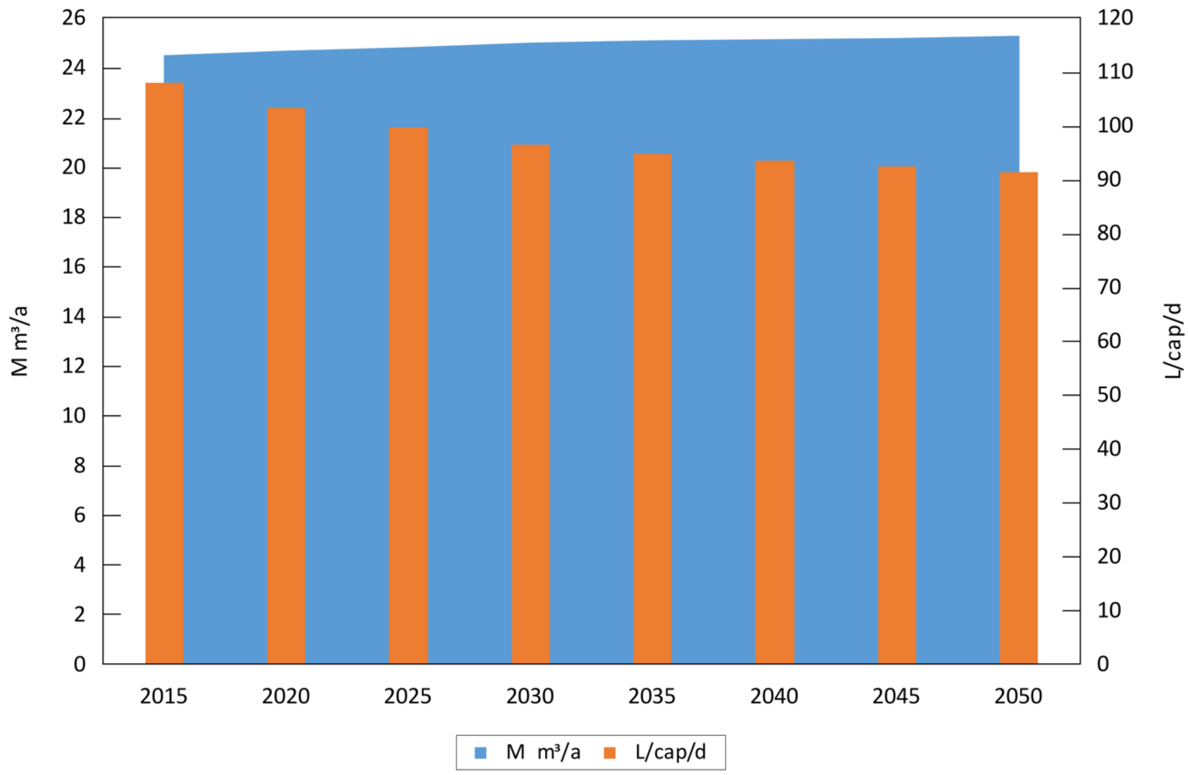


Figure A 4: The first forecast version of the total water consumption (M m^3/a) and the average consumption (L/cap/d) for Helsinki until 2050. The total consumption on the left y-axes is presented as a blue plane. The future per person consumption on the right y-axes is presented with the orange bars and in 5-year-steps.

A look at figure A 4 shows, that the total consumption was increasing from 24.53 M m^3/a in 2015 to 25.33 M m^3/a in 2050. On the other hand, the consumption per person was decreasing from 108.23 L/cap/d in 2015 to 91.52 L/cap/d in 2050. Compared to the first forecast version the increase of the total consumption was lower, and had with 24.66 M m^3/a its maximum in 2020 (Figure A 5). After this the total consumption decreased to 24.53 M m^3/a in 2050. Compared to the total consumption in 2015 with 24.50 M m^3/a, the total consumption increased until 2050. Another difference to the first forecast version was the amount about which the consumption per person was decreasing between 2015 and 2050. With 19.51 L/cap/d the decrease was 2.8 L/cap/d higher than in the first version. The consumption per person was 88.63 L/cap/d in 2050.

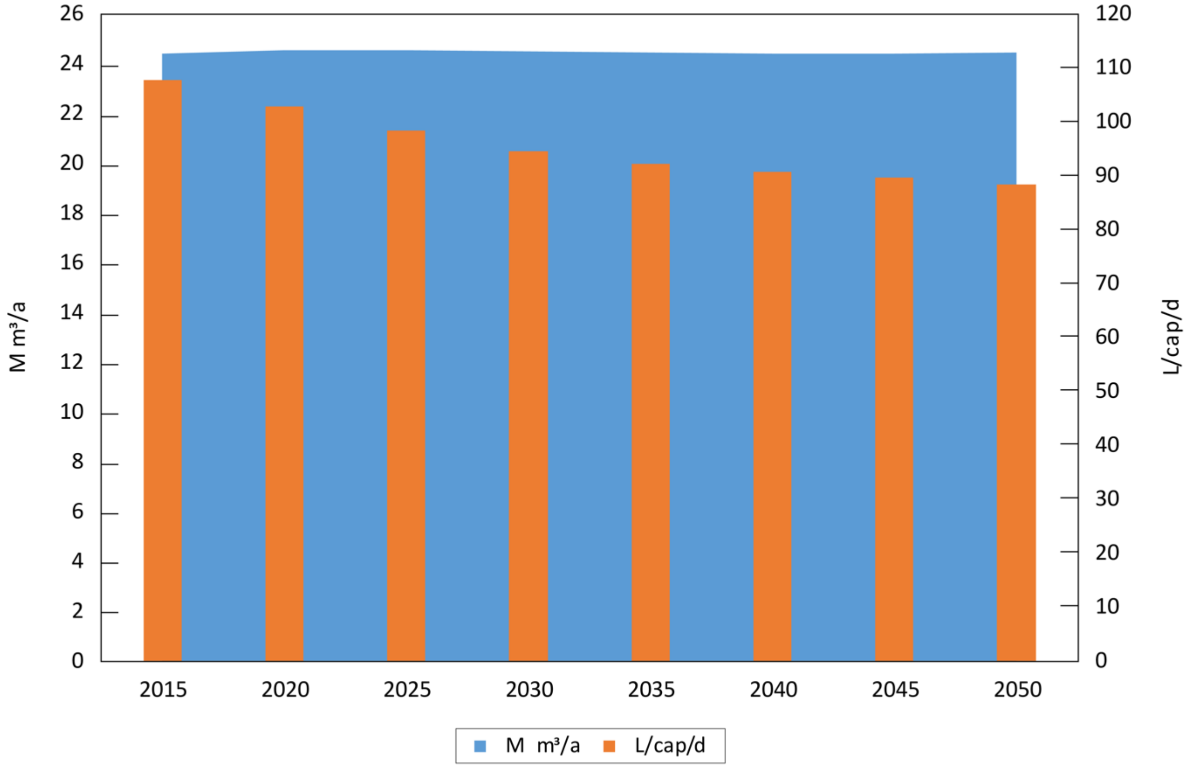


Figure A 5: The second forecast version of the total water consumption (M m^3/a) and the average consumption (L/cap/d) for Helsinki until 2050. The total consumption on the left y-axes is presented as a blue plane. The future per person consumption on the right y-axes is presented with the orange bars and in 5-year-steps.

b) City Espoo

Also in Espoo, the total consumption was increasing while the per person consumption was decreasing but the amount differed. Compared to the city Helsinki the total consumption was around 14 M m^3/a lower in Espoo.

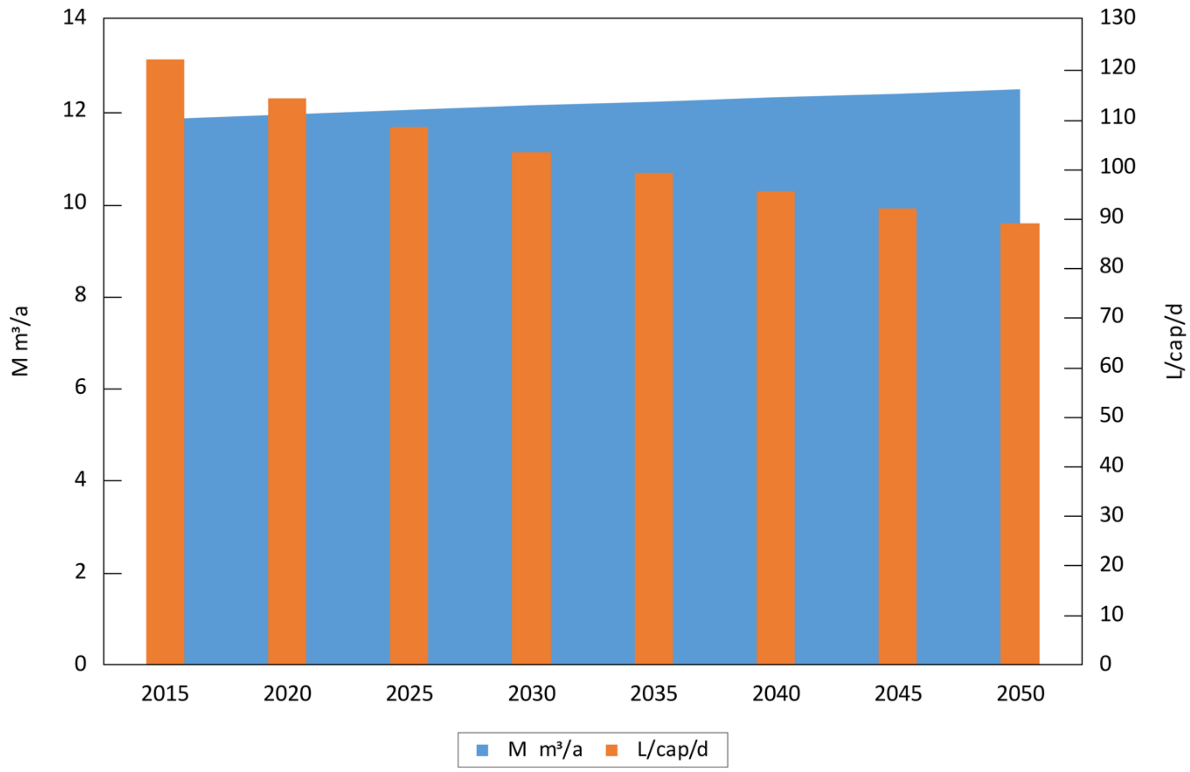


Figure A 6: The first forecast version of the total water consumption (M m^3/a) and the average consumption (L/cap/d) for Espoo until 2050. The total consumption on the left y-axes is presented as a blue plane. The future per person consumption on the right y-axes is presented with the orange bars and in 5-year-steps.

A look at figure A 6 shows, that the total consumption was increasing from 11.86 M m^3/a in 2015 to 12.52 M m^3/a in 2050. On the other hand, the per person consumption was decreasing from 122.38 L/cap/d in 2015 to 89.11 L/cap/d in 2050. Compared to the first forecast version the increase of the total consumption was lower, and had with 11.06 M m^3/a its maximum in 2020 (Figure A 7). After this the total consumption decreased to 11.03 M m^3/a in 2050. Compared to the consumption in 2015 with 10.98 M m^3/a, the consumption increased until 2050. Another difference to the first forecast version was the amount about which the per person consumption was decreasing between 2015 and 2050. With 34.77 L/cap/d the decrease was 1.5 L/cap/d higher than in the first version. Therefore, the increase per person between 2015-2050 was in Espoo higher than in Helsinki. This could be connected to a bigger potential for new buildings or renovations in the future. The per person consumption was 78.55 L/cap/d in 2050.

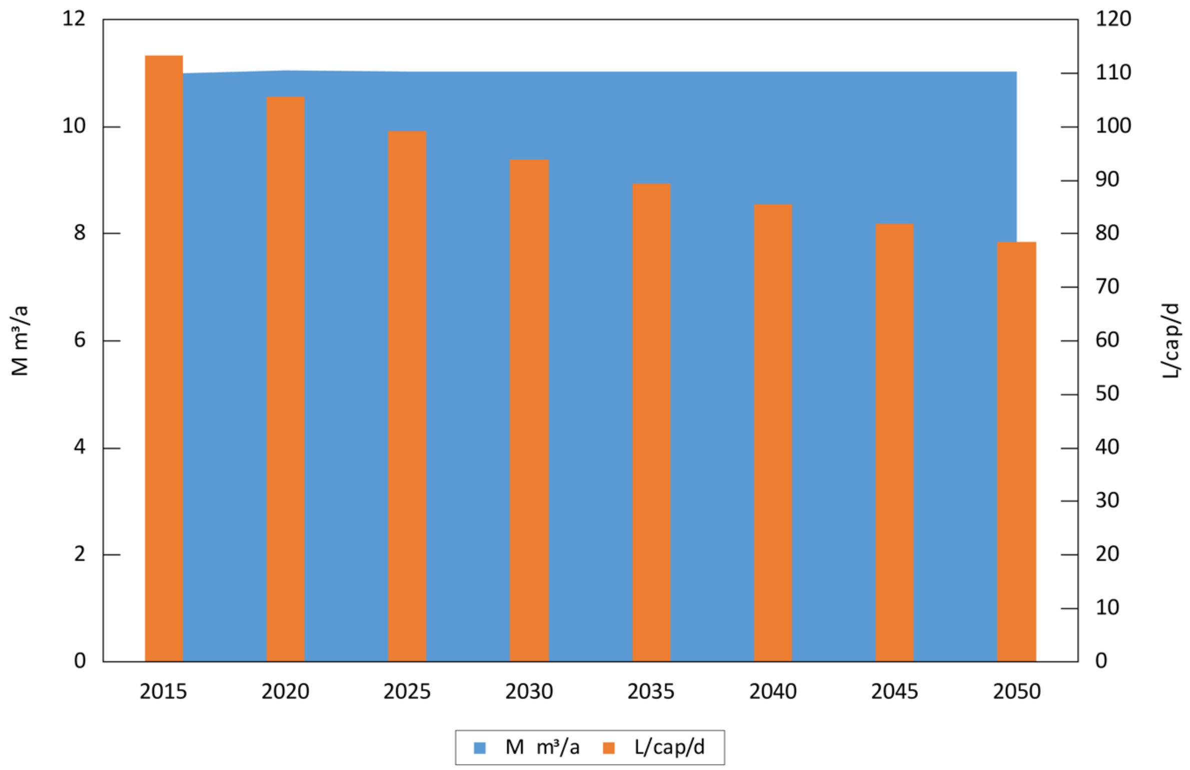


Figure A 7: The second forecast version of the total water consumption (M m^3/a) and the average consumption (L/cap/d) for Espoo until 2050. The total consumption on the left y-axes is presented as a blue plane. The future per person consumption on the right y-axes is presented with the orange bars and in 5-year-steps.

c) City Vantaa

Also in Vantaa, the total consumption was increasing while the per person consumption was decreasing. Compared to the city Helsinki the consumption was around 15 M m^3/a lower in Vantaa.

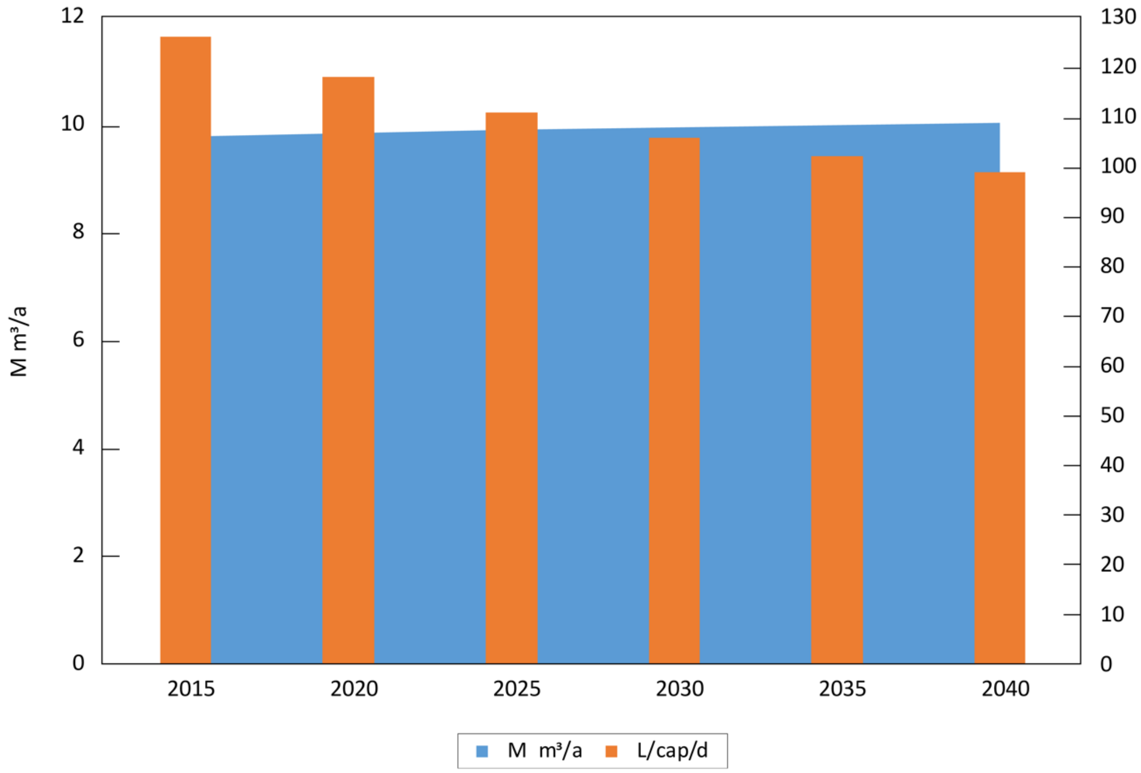


Figure A 8: The first forecast version of the total water consumption (M m^3/a) and the average consumption (L/cap/d) for Vantaa until 2050. The total consumption on the left y-axes is presented as a blue plane. The future per person consumption on the right y-axes is presented with the orange bars and in 5-year-steps.

A look at figure A 8 shows, that the total consumption was increasing from 9.81 M m^3/a in 2015 to 10.07 M m^3/a in 2040. On the other hand, the consumption per person was decreasing from 126.51 L/cap/d in 2015 to 99.20 L/cap/d in 2040. According to the first forecast version the increase of the total consumption was lower and had with 9.45 M m^3/a its maximum in 2020 (Figure A 9). After this the total consumption decreased to 9.39 M m^3/a in 2040. Compared to the total consumption in 2015 with 9.41 M m^3/a, the consumption increased until 2040. Another difference to the first forecast version was the amount about which the consumption per person was decreasing between 2015 and 2040. With 28.86 L/cap/d the decrease was 1.55 L/cap/d higher than in the first version. Also in Vantaa, the increase of the consumption per person between 2015-2040 was higher than in Helsinki and the reasons is properly the same as in Espoo. The consumption per person was 92.54 L/cap/d in 2040.

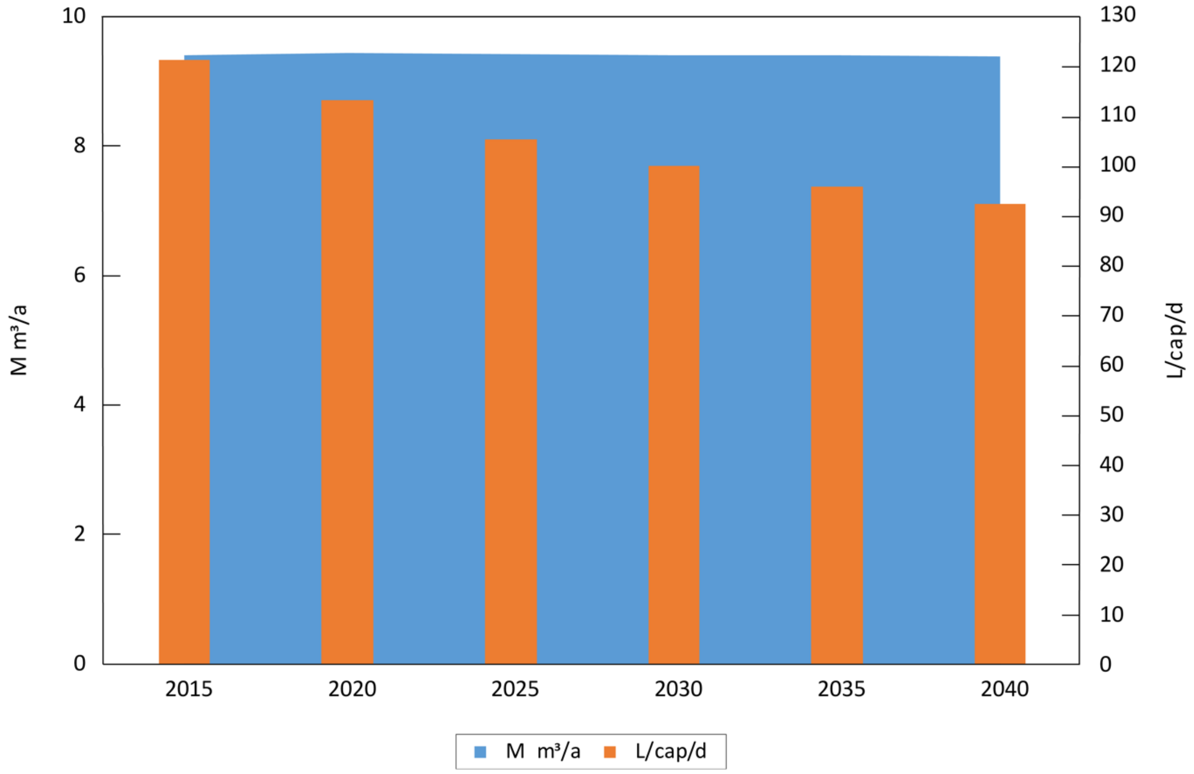


Figure A 9: The second forecast version of the total water consumption (M m^3/a) and the average consumption (L/cap/d) for Vantaa until 2050. The total consumption on the left y-axes is presented as a blue plane. The future per person consumption on the right y-axes is presented with the orange bars and in 5-year-steps.

APPENDIX 7 – STATISTICAL EVALUATION

Table A 7: Overview results of the statistical Evaluation (p-value, R^2)

Research Topic	Category	p-Value	R^2
		x1	Ordinary
water consumption [M m^3/a]	HSK	0.00001	0.89186
	HH	0.79738	0.00771
water consumption [L/cap/d]	HSK	0.00001	0.89186
	HH	0.79738	0.00771
water consumption depending on the age [L/cap/d]	under 25	0.16918	0.19889
	under 30	0.56480	0.03817
	under 45	0.71232	0.01584
	under 50	0.36542	0.09169
	under 68	0.06105	0.33718
	over 68	0.99689	0.00000
water consumption depending on the household size [L/cap/d]	size 1	0.00109	0.71241
	size 2	0.40158	0.07928
	size 3-4	0.11879	0.24826
	size 5-6	0.08780	0.28944
	size 7-10	0.18242	0.18827
	size 11-14	0.64834	0.02413
water consumption depending on the building age [L/cap/d]	1900-1950	0.00079	0.73144
	1950-1965	0.00043	0.76398
	1965-1980	0.02531	0.44338
	1980-1990	0.07651	0.30777
	1990-2000	0.24366	0.14745
	2000-2014	0.34725	0.09851
water consumption deepening on common/individual water meter [L/cap/d]	1980-1990	0.89834	0.01033
	1990-2000	0.84531	0.02393
	2000-2010	0.27121	0.53113
	after 2011	0.59692	0.16247
dependence of the water consumption and the income suupiiri [L/cap/d]	2008	0.45977	0.11359
	2011	0.60127	0.05851
	2014	0.95634	0.00066
dependence of the water consumption and the income group [L/cap/d]	2008	0.82425	0.00654
	2011	0.70152	0.01935
	2014	0.01792	0.52413

APPENDIX 8 – OVERVIEW ANALYSIS INPUT DATA POINTS

a) Average household age

Table A 8: Overview number of input data for the analysis of the average household age

	2004			2005			2006		
	Average Amount People	Amount of People per Group	Amount of Households	Average Amount People	Amount of People per Group	Amount of Households	Average Amount People	Amount of People per Group	Amount of Households
≤25	5.00	25,556	5,113	4.91	31,819	6,479	4.94	31,542	6,384
26-30	4.95	18,333	3,707	4.89	20,726	4,238	4.85	21,526	4,442
31-45	4.57	40,789	8,927	4.49	43,395	9,666	4.37	43,756	10,022
46-50	3.68	8,021	2,178	3.55	9,602	2,708	3.39	9,120	2,688
51-68	2.44	19,640	8,033	2.54	20,382	8,031	2.44	20,773	8,515
≥68	1.82	3,711	2,035	1.84	4,627	2,517	1.75	4,484	2,567
	2007			2008			2009		
≤25	4.97	26,577	5,351	4.88	19,639	4,023	4.91	24,851	5,057
26-30	4.85	20,879	4,309	4.90	17,217	3,517	4.88	20,296	4,155
31-45	4.39	41,871	9,536	4.43	34,933	7,892	4.45	40,073	9,014
46-50	3.64	7,830	2,152	3.88	6,663	1,716	3.85	7,489	1,947
51-68	2.41	21,283	8,824	2.38	18,942	7,946	2.42	21,536	8,889
≥68	1.81	5,472	3,017	1.78	4,473	2,517	1.82	5,640	3,104
	2010			2011			2012		
≤25	4.93	21,261	4,309	4.94	21,044	4,257	4.94	20,113	4,072
26-30	4.93	19,592	3,972	4.95	19,190	3,873	4.92	18,046	3,671
31-45	4.49	40,604	9,045	4.45	40,939	9,210	4.48	41,541	9,264
46-50	3.86	7,509	1,947	3.84	7,923	2,064	3.83	7,992	2,087
51-68	2.47	21,578	8,727	2.46	22,442	9,127	2.48	22,951	9,270
≥68	1.84	6,188	3,361	1.83	6,704	3,666	1.84	7,070	3,837
	2013			2014					
≤25	4.94	21,556	4,362	4.86	19,433	4,000			
26-30	4.93	18,093	3,673	4.93	17,589	3,568			
31-45	4.45	40,114	9,005	4.48	41,485	9,259			
46-50	3.81	7,803	2,046	3.78	7,773	2,055			
51-68	2.49	23,083	9,283	2.53	24,128	9,536			
≥68	1.84	7,088	3,858	1.85	8,129	4,405			

b) Household size

Table A 9: Overview number of input data for the analysis of the household size

	2004			2005			2006		
	Average Amount People	Amount of People per Group	Amount of House Holds	Average Amount People	Amount of People per Group	Amount of House Holds	Average Amount People	Amount of People per Group	Amount of House Holds
1 cap	1.00	1,816	1,816	1.00	1,830	1,830	1.00	2,354	2,354
2 cap	2.00	16,196	8,098	2.00	17,136	8,568	2.00	19,080	9,540
3-4 cap	3.54	41,369	11,685	3.52	49,145	13,965	3.53	47,964	13,570
5-6 cap	5.33	27,400	5,137	5.32	30,248	5,684	5.32	29,585	5,563
7-10 cap	8.09	20,716	2,560	8.07	22,864	2,832	8.05	22,671	2,815
11-14 cap	12.27	8,553	697	12.27	9,328	760	12.30	9,547	776
	2007			2008			2009		
1 cap	1.00	2,453	2,453	1.00	2,690	2,690	1.00	2,874	2,874
2 cap	2.00	19,452	9,726	2.00	16,464	8,232	2.00	18,712	9,356
3-4 cap	3.56	44,330	12,465	3.55	34,721	9,769	3.57	41,685	11,682
5-6 cap	5.33	27,680	5,194	5.34	21,152	3,964	5.33	25,787	4,842
7-10 cap	8.03	20,996	2,616	8.09	18,186	2,249	8.09	21,293	2,633
11-14 cap	12.25	9,001	735	12.24	8,654	707	12.24	9,534	779
	2010			2011			2012		
1 cap	1.00	2,867	2,867	1.00	3,104	3,104	1.00	3,198	3,198
2 cap	2.00	18,232	9,116	2.00	19,164	9,582	2.00	19,252	9,626
3-4 cap	3.57	40,455	11,325	3.57	41,135	11,537	3.56	40,916	11,492
5-6 cap	5.33	25,145	4,721	5.33	24,801	4,656	5.33	24,407	4,580
7-10 cap	8.10	21,067	2,600	8.07	20,453	2,534	8.06	20,270	2,514
11-14 cap	12.25	8,966	732	12.23	9,585	784	12.23	9,670	791
	2013			2014					
1 cap	1.00	3,172	3,172	1.00	3,403	3,403			
2 cap	2.00	19,346	9,673	2.00	20,066	10,033			
3-4 cap	3.55	41,035	11,547	3.55	41,381	11,664			
5-6 cap	5.34	24,200	4,535	5.35	23,691	4,429			
7-10 cap	8.08	20,351	2,519	8.06	20,017	2,482			
11-14 cap	12.33	9,633	781	12.29	9,979	812			

c) Building year

Table A 10: Overview number of input data for the analysis of the building year

	1900-1949			1950-1964			1965-1979		
	Average Age People	Amount People	Amount of House Holds	Average Age People	Amount People	Amount of House Holds	Average Age	Amount People	Amount of House Holds
2004	43.16	96,625	4,795	46.88	126,870	8,824	46.89	212,932	8,547
2005	43.12	96,948	4,953	46.64	128,314	9,259	46.97	213,758	8,829
2006	43.29	97,417	5,100	46.77	128,079	9,500	47.25	213,794	8,963
2007	43.68	97,245	5,111	47.17	127,355	9,521	47.68	212,144	8,983
2008	44.12	97,144	5,127	47.59	126,869	9,550	48.08	210,689	8,994
2009	44.21	98,242	5,133	47.66	128,388	9,514	48.34	212,322	9,025
2010	45.29	93,773	5,005	48.68	106,091	8,686	49.26	207,739	8,798
2011	45.27	94,391	5,029	48.89	106,957	8,673	49.42	208,197	8,830
2012	45.86	94,528	5,009	49.22	107,230	8,610	49.77	208,188	8,801
2013	45.71	91,629	4,907	49.32	99,487	8,325	49.57	202,036	8,675
2014	46.20	91,098	4,885	49.84	92,224	8,063	50.03	199,225	8,601
	1980-1989			1990-1999			2000-2014		
2004	42.66	160,575	9,991	33.32	159,233	7,217	29.11	51,313	2,742
2005	43.31	159,667	10,225	34.15	158,218	7,385	28.48	79,382	4,919
2006	44.03	157,453	10,325	35.02	155,964	7,434	29.17	106,982	6,983
2007	44.79	155,440	10,355	35.87	154,025	7,459	29.84	115,055	6,341
2008	45.56	153,715	10,370	36.72	152,293	7,469	30.72	115,076	7,007
2009	46.26	154,133	10,401	37.54	152,036	7,520	31.26	123,366	7,696
2010	47.46	150,494	10,326	39.05	148,642	7,497	32.39	135,645	8,512
2011	47.92	149,524	10,345	39.74	147,891	7,519	32.86	131,578	8,636
2012	48.48	149,321	10,357	40.61	147,027	7,517	33.26	128,662	8,791
2013	48.36	146,664	10,320	40.74	144,970	7,522	33.09	133,297	9,134
2014	49.17	145,549	10,318	42.22	144,967	7,528	34.41	143,206	9,833

d) Water meter

Table A 11: Overview number of input data for the analysis of the difference between common and individual water meter

	2011			2012		
	Average Amount People	Amount of People per Group	Amount of House Holds	Average Amount People	Amount of People per Group	Amount of House Holds
1980-1989	14.45	149,524	10,345	19.67	147,891	10,357
1990-1999	14.42	149,321	7,519	19.56	147,027	7,517
2000-2010	14.21	146,664	8,379	19.27	144,970	7,985
after 2011	14.11	145,549	257	19.26	144,967	806
	2013			2014		
	Average Amount People	Amount of People per Group	Amount of House Holds	Average Amount People	Amount of People per Group	Amount of House Holds
1980-1989	15.32	128,335	10,320	12.62	3,243	10,318
1990-1999	14.74	117,698	7,522	13.60	10,964	7,528
2000-2010	14.70	117,566	8,000	13.87	15,731	8,021
after 2011	14.55	116,680	1,134	14.64	26,526	1,812

e) Income

Table A 12: Overview number of input data for the analysis of the influence of the income

	2008		2011		2014	
	population	amount districts	population	amount districts	population	amount districts
<20,000	700	2	1,133	2	860	1
20,000–22,499	22,539	16	9,746	6	3,301	3
22,500-24,999	41,571	22	53,027	19	32,356	15
25,000-29,999	121,159	22	98,456	28	101,892	26
30,000–34,999	51,851	21	78,193	19	72,031	20
35,000-44,999	111,131	16	101,644	22	76,918	22
45,000–54,999	8,944	5	18,325	7	41,483	9
55,000–74,999	1,219	2	6,312	5	15,426	6
75,000-99,999	5	1	1,142	1	2,102	3
≥100,000	9,397	3	1,257	2	804	2